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DE LA
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SOCIÉTÉ ENTOMOLOGIQUE D'EGYPTE

(Société Royale Entomologique d'Egypte (1922 - 1937)

et Société Fouad I^{er} d'Entomologie (1938 - 1954))



FONDÉE LE 1^{er} AOUT 1907

PLACÉE SOUS LE HAUT PATRONAGE DU GOUVERNEMENT EGYPTIEN
PAR DÉCRET EN DATE DU 15 MAI 1923

LE CAIRE
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1956

Le Rédacteur en Chef :
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Les auteurs reçoivent gratuitement 50 tirés à part de leurs travaux ; toute quantité supplémentaire sera facturée au prix courant.

Pour la correspondance administrative et scientifique, échanges de Publications, changement d'adresse et réclamations, s'adresser à Monsieur le Secrétaire Général de la Société Entomologique d'Egypte, Boîte Postale No. 430, Le Caire.

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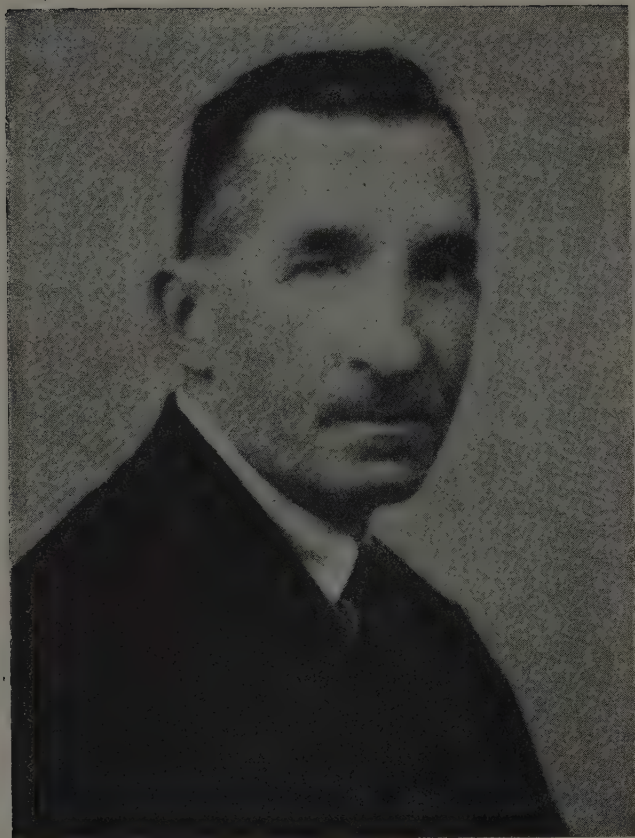
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Frank C. Willcocks
1936

Frank C. Willcocks

1883-1955

Le 18 Décembre 1955, notre éminent collègue Frank C. Willcocks s'éteignait dans son cottage de Saddlescombe (Sussex).

Né le 22 Juillet 1883, Willcocks fit ses études supérieures au South Eastern Agricultural College de Wye (Kent), où il décroche ses diplômes d'agronome et d'entomologiste. En Octobre 1904, il entre au service de la Société Egyptienne d'Agriculture, et y dirige le laboratoire d'entomologie pendant 26 années consécutives. Pionnier de l'entomologie agricole égyptienne, il fut également un des fondateurs de la Société Entomologique d'Egypte, et son Vice-Président en 1917 et 1922. Lorsqu'en 1930 il mit fin à son service et qu'il quitta l'Egypte pour s'installer dans sa Patrie, notre Société lui conféra le titre de Membre Honoraire à vie, en reconnaissance des signalés services qu'il avait rendus au Pays et à la Science. Willcocks n'eut que des amis, car sa vie fut un exemple de modestie et de noblesse. Il est mort; mais son œuvre ne perira pas, et c'est aussi par là qu'il restera toujours vivant parmi nous.

On trouvera, ci-après, la liste de ses publications entomologiques relatives à l'Egypte.

(1) Insects injurious to the cotton plant in Egypt, part I (Year-Book of the Khedivial Agricultural Society, pp. 15-116, Cairo, 1905).

(2) Notes on the Egyptian Cotton Bug or Cotton Stainer (*loc. cit.*, pp. 11-28, Cairo, 1906).

(3) Insects injurious to stored grains, seeds, etc., with special reference to their occurrence in Egypt (*loc. cit.*, pp. 195-222, Cairo, 1909).

(4) List of other grain-feeding insects known to occur in Egypt, with some notes on their life-histories and economic importance (*loc. cit.*, pp. 223-227, Cairo, 1909).

(5) Le Coléoptère du Lebbek, *Xystrocera globosa* Oliv. (*Bull. Soc. Ent. Egypte*, II, 1909, pp. 42-49).

(6) Miscellaneous notes on Egyptian insects (*loc. cit.*, III, 1912, pp. 136-138).

(7) Miscellaneous notes on Egyptian insects and mites (*loc. cit.*, III, 1912, pp. 142-144).

(8) Notes on some injurious and beneficial mites found in Egypt (*loc. cit.*, III, 1913, pp. 15-18).

- (9) The Date-Stone beetle (*loc. cit.*, III, 1913, pp. 37-39).
- (10) Note préliminaire sur un *Bracon* sp., insecte parasite du ver de la capsule du cotonnier (*Earias insulana* Boisd.) (*loc. cit.*, III, 1913, pp. 56-67).
- (11) An parasite of the Pink Bollworm, *Pediculoides ventricosus* (*loc. cit.*, III, 1913, pp. 68-72).
- (12) Sur un Coléoptère nuisible aux Melons (*loc. cit.*, III, 1913, page 82).
- (13) Some notes on the Mealy Plum Aphid: *Hyalopterus pruni* Fabricius (*loc. cit.*, IV, 1916, pp. 33-37).
- (14) Miscellaneous insect notes (*loc. cit.*, IV, 1916, pp. 100-108).
- (15) The Insect and related pests of Egypt. — Vol. I : The Insect and related pests injurious to the cotton plant. — Part I : The Pink Bollworm (340 pages, illustrations and plates, Sultanic Agricultural Society, Cairo, 1916).
- (16) Notes on Insects found in Egypt of medical and Veterinary interest (*Bull. Soc. Ent. Egypte*, V, 1917, pp. 79-90).
- (17) A Survey of the more important economic insects and mites of Egypt, with notes on life-history, habits, natural enemies, and suggestions for control (*Bull. No. 1*, pp. i-vii and I-483, Sultanic Agricultural Society, Cairo, 1922).
- (18) The Insect and related pests of Egypt. — Vol. II : Insects and Mites feeding on gramineous crops and products in the field, granary, and mill (376 pages, illustrations and plates, Sultanic Agricultural Society, Cairo, 1925).
- (19) The Insect and related pests of Egypt. — Vol. I, part II : Insects and Mites injurious to the Cotton plant (792 pages, illustrations and plates, Royal Agricultural Society, Cairo, 1937 [in collaboration with Said Bahgat]).
-

Drei neue Miriden-Arten aus Aegypten und Bemerkungen zu einer bereits bekannten Art

R

[Hemiptera-Heteroptera]

(mit 28 Abbildungen)

VON EDUARD WAGNER, Hamburg.

Von Herrn Prof. H. Priesner, Kairo, erhielt ich eine kleine Sendung zweifelhafter Heteropteren-Arten aus Aegypten. Die Bearbeitung dieses Materials ergab 3 fuer die Wissenschaft neue Arten aus der Familie der Miridae und ermoglichte es, die Beschreibung einer 4-Art zu vervollstaendigen. Herrn Prof. Priesner sei auch an dieser Stelle fuer die Uberlassung des Materials bestens gedankt.

1. *Cyrtopeltis* (*Cyrtopeltis*) *pygmaea* nov. spec.

Von sehr kleiner, schlaenker Gestalt (Fig. 1), ♂+♀ $3,33\times$ so lang wie das Pronotum breit ist. Hell weisslich gruenn, nach dem Tode weisslich-ocker-gelb; mit schwarzer Zeichnung, die bei einigen Stuecken dunkelrot ist (unreif). Oberseits mit langen, gekruemmtem, schraegstehenden, weisslichen Haaren, zwischen denen einzelne, kraeftigere, schwarzbraune oder schwarze Haare sitzen. Makropter.

Kopf hell, stark gewoelbt, breiter als lang. Auge gross, dunkelgrau bis schwarz. Scheitel beim ♂ $1,66\times$, beim ♀ $1,8\times$ so breit wie das Auge. Hinter den Augen ist der Kopf nur kurz, seine Seiten sind fast parallel. Fuehler kurz und kraeftig; 1. Glied schwarz, an Grund und Spitze weisslich, nur $0,8\times$ so lang wie der Scheitel breit ist; 2. Glied gelbbraun, an Grund und Spitze ebenfalls weisslich, nahe dem Grunde ein schwarzer Ring und vor der Spitze etwas dunkler braun, nur weing laenger als der Kopf samt Augen breit ist und $2,6-2,7\times$ so lang wie das 1.; 3. Glied braun, hinter dem weisslichen Grunde ein dunkelbrauner Ring, beim ♂ $0,84\times$, beim ♀ $0,9\times$ so

lang wie das 2. und $1,4-1,5\times$ so lang wie das 4., letzteres dunkelbraun.

Pronotum trapezförmig. Halsring breit und deutlich. Schwielen klein aber verhältnismässig stark gewölbt. Hinterrand mit 2 flachen Einbuchtungen (Fig. 1). Scutellum gross, sein Grund frei. Halbdecken fast parallelseitig, der Hinterrand des Corium, die Spitze des Clavus und ein breiter Fleck an der Cuneusspitze dunkel. Membran hell, durchscheinend, Adern braunlich.

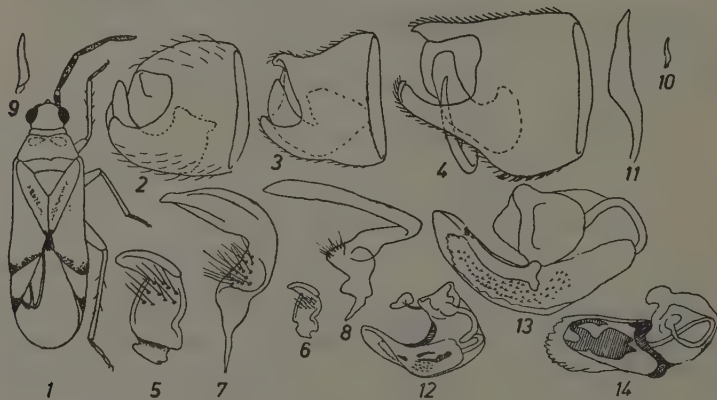


Fig. 1-14 : *Cyrtopeltis* :

Fig. 1 : *C. pygmaea* nov. spec. ♂ (16×). — Fig. 2 : Genitalsegment von *C. pygmaea* nov. spec. ♂ (67×). — Fig. 3 : Dasselbe von *C. geniculata* Fieb. (25×). — Fig. 4 : Dasselbe von *C. tenuis* Reut. (53×). — Fig. 5 : Linker Genitalgriffel von *C. pygmaea* nov. spec. (135×). — Fig. 6 : Derselbe (67×). — Fig. 7 : Linker Griffel von *C. geniculata* Fieb. (67×). — Fig. 8 : Linker Griffel von *C. tenuis* Reut. (67×). — Fig. 9 : Rechter Griffel von *C. pygmaea* nov. spec. (135×). — Fig. 10 : Derselbe (67×). — Fig. 11 : Rechter Griffel von *C. geniculata* Fieb. (67×). — Fig. 12 : Penis von *C. pygmaea* nov. spec. (67×). — Fig. 13 : Penis von *C. geniculata* Fieb. (55×). — Fig. 14 : Penis von *C. tenuis* Reut. (67×).

Unterseite einfarbig gruenlich. Das Rostrum hat eine schwarze Spitze und reicht bis zwischen die Mittelhueften. Beine schlank aber verhältnismässig kurz, einfarbig gruenlich oder braeunlich, mit feiner Behaarung. Schienen ausserdem mit einigen schwarzen Dornen. Tarsen hell, distal dunkler. An den hinteren Tarsen ist das 1. Glied das kuerzeste und das 2. das laengste.

Genitalsegment des ♂ (Fig. 2) etwas kuerzer als hoch, fast kugelig. Unterer Rand der Genitalöffnung leicht aufwaerts gewölbt, ohne auffaelligen Fortsatz, oberer Rand leicht vorstehend ebenfalls ohne Fortsatz. Linker Genitalgriffel (Fig. 5+6) kurz und dick, Hypophysis deutlich, kurz, gekruemt, distal stumpf, Paramerenkoerper mit einer Gruppe langer, kraeftiger Borsten, Basis klein. Rechter Griffel (Fig. 9+10) sehr klein, gerade,

schlank. Penis (Fig. 12) distal schlank, Basis breit. In der Vesica traegt der ventrale membranöse Anhang eine Anzahl Chitinzaehne, daneben finden sich 3-4 Chitinstaebe (spicula). Sekundaere Gonopore undeutlich.

Laenge : ♂ = 1,85-2,05 mm., ♀ = 1,95-2,05 mm.

C. pygmaea nov. spec. muss nach der Arbeit von China und Carvalho (1952) ⁽¹⁾ in die Untergattung *Cyrtopeltis* s. str. eingeordnet werden. Das Genitalsegment (Fig. 2) zeigt weder am oberen noch am unteren Rande der Genitalöffnung einen auffaelligen Fortsatz und die Vesica des Penis (Fig. 12) hat die fuer *Cyrtopeltis* s. str. charakteristischen Chitinzaehne. Damit hat diese Untergattung nunmehr 3 Arten. Die beiden bisher bekannten Arten weichen von unserer neuen Art schon durch ihre Grösse erheblich ab. Ausserdem unterscheidet sich *C. pygmaea* von ihnen durch die kurzen, kraeftigen Fuehler, kuerzere Beine, das gewölbtere Auge, die Fleckung von Corium und Cuneus, die gruene Faerbung und den Bau der Genitalien des ♂. *C. geniculata* Fieb. ist 4,8-5 mm. lang, der Scheitel ist etwa $2,5 \times$ so breit wie das flache Auge. *C. canariensis* Lindbg. ist 3,9-4,1 mm. lang, der Scheitel ist $1,5 \times$ (♂) bis $2,0 \times$ (♀) so breit wie das Auge. Die bisher als *Engytatus tenuis* Reut. bezeichnete Art muss nach China und Carvalho (l.c.) ebenfalls in die Gattung *Cyrtopeltis* gestellt werden und gehoert dort zur Untergattung *Nesidiocoris* Kirk., muss also jetzt *Cyrtopeltis* (*Nesidiocoris*) *tenuis* Reut. heissen. Sie unterscheidet sich von unserer neuen Art durch weit grössere Gestalt, den Bau des Genitalsegments des ♂ (Fig. 4), das am unteren Rande der Genitalöffnung einen langen Fortsatz hat und den schlanken linken Griffel (Fig. 8).

Die Art lebt an *Trichodesma africanum*.

Ich untersuchte 6♂♂ und 4♀♀ aus Aegypten : Abusir (Pyramiden) 8.1.55 5♂♂, 3♀♀, Wadi Firan 14.5.34 1♀ und St. Katrien 16.5.34 1♂, saemtlich H. Priesner leg.

Holotypus und Allotypoid in meiner Sammlung, Paratypoiden ebenda und in der Sammlung der Ein Shams Universitaet.

Tabelle der palaearktischen Arten von *Cyrtopeltis* Fieb.

- 1a Unterer Rand des ♂-Genitalsegments mit einem langen Fortsatz (Fig. 4) oberer Rand in einen langen Lappen vorgezogen, der ebenso weit nach hinten reicht wie der untere Fortsatz. Linker Griffel (Fig. 8) sehr lang und schlank, nahe dem Grunde stark gebogen. Lange 3.4-3.8mm. (Subgen. *Nesidiocoris* Kirk.).....1. ***C. tenuis* Reut.**
- 1b Unterer Rand der Genitalöffnung des ♂ ohne auffaelligen Fortsatz

⁽¹⁾ The *Cyrtopeltis*-Complex (*Ann. Mag. Nat. Hist.*, XII (5) : 158-166).

(Fig. 2) oberer Rand kaum vorgezogen. Linker Genitalgriffel dick, kurz (Fig. 5), mit deutlicher Hypophysis (Subgen. *Cyrtopeltis* s. str.).

- 2a Laenge 1,85-2,05 mm. Scheitel beim ♂ 1,66×, beim ♀ 1,8× so breit wie das Auge. Aegypten.....2. **C. pygmaea nov. spec.**
 2b Laenge ueber 3,5 mm.
 3a Auge sehr flach, Scheitel etwa 2,5× so breit wie das Auge. Laenge 4,8-5,5 mm. Westliches Mittelmeergebiet.....3. **C. geniculata Fieb.**
 3b Auge gewölbt, Scheitel beim ♂ 1,5×, beim ♀ 2,0× so breit wie das Auge. Laenge 3,9-4,1 mm. Kanaren.....4. **C. canariensis Ldbg.**

2. *Orthotylus (Melanotrichus) pusillus* Reut. 1883

In seiner Beschreibung der obigen Art (Hem. Gymn. Eur. III: 273-274) beschreibt Reuter nur das ♀ (das in der 4. Zeile gesetzte ♂ - Zeichen ist augenscheinlich ein Druckfehler) und auch diese Beschreibung ist lückenhaft, da die Behaarung des der Beschreibung zugrundeliegenden Stückes abgerieben war, wie Reuter angibt. Unter den mir von Herrn Prof. Priesner gesandten Tieren waren 5 Exemplare der Art, so dass es mir möglich ist, hier die Beschreibung des ♂ zu geben.

Beschreibung des ♂ : Von kleiner, laenglich-ovaler Gestalt, 3,2× so lang wie das Pronotum hinten breit ist. Weisslich-ockergelb bis lebhaft grün, die Halbdecken stets grün. Oberseits mit doppelter Behaarung. Zwischen den kraeftigen, halbaufgerichteten, gekrümmten Haaren sitzen

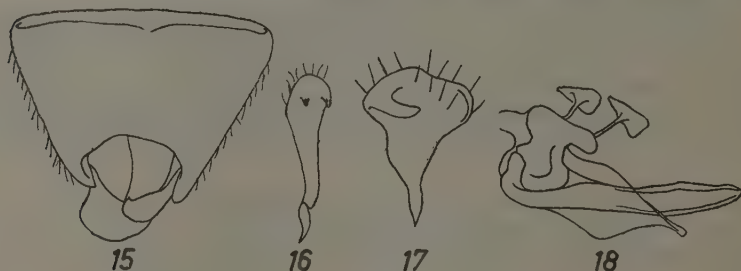


Fig. 15-18 : *Orthotylus pusillus* Reut., Genitalien des ♂ :

Fig. 15 : Genitalsegment von oben (84×). — Fig. 16 : Rechter Griffel (120×). — Fig. 17 : Linker Griffel (120×). — Fig. 18 : Penis (120×).

kurze, silberglaenzende Schuppenhaare. Auch diese halbaufgerichteten Haare sind weisslich, nur im hinteren Teil des Corium und im Cuneus erscheinen sie braeunlich. Glaenzend, fein punktiert. Makropter.

Kopf kurz und breit, Scheitel hinten fein, aber undeutlich gerandet, 2,2× so breit wie das braune Auge. Fühler hell lehmgelb, mit feiner, dunkler

Behaarung; 1. Glied etwa so lang wie das Auge breit ist, mit einzelnen, langen Borsten; 2. Glied stabförmig, etwa so lang wie das Pronotum hinten breit ist; das 3. Glied $0,8 \times$ so lang wie das 2. und mehr als doppelt so lang wie das 4.

Pronotum kurz und breit, am Hinterrand $1,3-1,4 \times$ so breit wie der Kopf. Schwielen undeutlich. Vorderer Teil des Pronotum oft hell ockergelb, ebenso das Scutellum. Halbdecken grün, Cuneus einfarbig grün. Membran hell rauchgrau, durchscheinend, Adern sattgrün. Beine hellgelb. Hinterschenkel verdickt. Schienen mit gleichfarbenen Dornen. Tarsen hell. An den Hinterbeinen ist die Schiene kurz und nur $2,75-2,80 \times$ so lang wie der Fuss (samt Klauen) und das 3. Tarsenglied etwa so lang wie das 2. Das Rostrum überragt die Hinterhüften deutlich.

Genitalsegment des ♂ (Fig. 15) kurz und breit, kegelförmig, auch die Genitalöffnung kurz und breit. Linker Genitalgriffel (Fig. 17) dreieckig, distal gerundet, Hypophysis auffaellig dick und stumpf, bis zur Mitte des Paramerenkörpers reichend, rechte Ecke des Griffels nur verdickt, ohne Zähne oder Höcker. Rechter Griffel (Fig. 16) keulenförmig, distal mit 2 kurzen Spitzen, Penis (Fig. 18) sehr klein und schlank, Chitinbaender glatt, unverzweigt, Theca distal schraeg abgestutzt.

Laenge : ♂ = 2,6 - 3,05 mm., ♀ = 2,5 - 2,7 mm.

O. pusillus Reut. gehoert in die Untergattung *Melanotrichus* Reut. (*Halocapsus* Put.) und ist eine der kleinsten Arten dieser Gruppe. Er unterscheidet sich von den meisten Arten der Untergattung durch die geringe Groesse, die sattgrünen Membranadern und die Form des linken Genitalgriffels des ♂, von *O. schoberiae* Reut. und *O. minutus* Jak. durch das lange Rostrum, laengere Fühler und kleinere Gestalt, von *O. parvulus* Reut. durch die lebhaft grün gefaerbten Membranadern, schwaecher gerandeten Scheitel und breitere Gestalt. Bei *O. pusillus* Reut. ist das ♂ nur wenig schlanker als das ♀, das etwa $2,9 \times$ so lang ist wie das Pronotum hinten breit ist.

Ich untersuchte 3♂♂ und 2♀♀ aus Aegypten : Wadi Digla 26.9.33 1♂, 2♀♀; Meadi 30.4.33 2♂♂ (saemtlich H. Priesner leg.).

3. *Orthotylus* (*Melanotrichus*) *haloxyloni* nov. spec.

Gestalt etwas groesser und schlanker als bei den verwandten Arten, $3 \times$ so lang wie das Pronotum breit ist. Hell weisslichgrün, an den Raendern der Halbdecken lebhaft grün. Behaarung zweifach, aus anliegenden, silberweissen Schuppenhaaren und laengeren, halbaufgerichteten, hell- oder dunkelbraunen Haaren bestehend. Makropter.

Kopf kurz. Scheitel gerandet, $2,2 \times$ so breit wie das Auge (♂). Fühler hell gelbbraun, mit feiner, heller, anliegender Behaarung; 1. Glied dick, mit einzelnen hellen Borsten, nur wenig laenger als das Auge breit ist; 2. Glied

stabförmig, gegen die Spitze dunkler, $1,1 \times$ so lang wie der Kopf samt Augen breit ist; 3. Glied $0,56-0,58 \times$ so lang wie das 2. und $1,5 \times$ so lang wie das 4., die beiden Endglieder dunkler.

Pronotum trapezförmig, Schwielen undeutlich. Schildgrund grössenteils bedeckt. Hinterrand des Corium, Innen- und Aussenrand des Cuneus grün oder dicht mit grünen Flecken bedeckt. Membran hell rauchgrau, Adern gelblichweiss.

Unterseite hell. Rostrum die Mittelhüften erreichend. Beine hellgelb, mit feiner, heller Behaarung, Tarsen hell. An den Hinterbeinen ist die Schiene $4,5 \times$ so lang wie der Fuss (ohne Klauen) und das 3. Tarsenglied etwas länger als das 2. Schienen mit feinen, hellen Dornen.

Genitalsegment des ♂ (Fig. 19) kurz und breit, mit langer Behaarung. Genitalöffnung sehr kurz und breit. Rechter Genitalgriffel (Fig. 20) gross, Hypophysis hakenförmig, sehr kraeftig, Paramerenkörper distal aussen mit einer Ecke, in der Mitte eingeschnürt, obere Aussenkante mit langen Haaren. Linker Griffel (Fig. 21) dreieckig, Hypophysis schlank und gekrümmt, die Mitte des Paramerenkörpers überragend, rechte Ecke

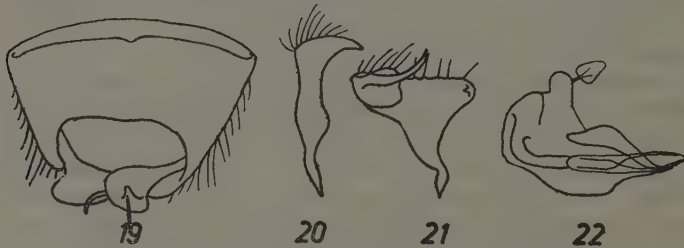


Fig. 19-22 : *Orthotylus haloxyloni* nov. spec., Genitalien des ♂ :

Fig. 19 : Genitalsegment von oben ($63 \times$). — Fig. 20 : Rechter Griffel seitlich ($84 \times$). — Fig. 21 : Linker Griffel von innen ($84 \times$). — Fig. 22 : Penis ($84 \times$).

des Griffels mit einem kleinen Zahn. Penis sehr klein und einfach (Fig. 22), Chitinbaender der Vesica einfach und unverzweigt.

Laenge : ♂ = 3,3-3,9 mm.

Das ♀ von *O. haloxyloni* n. sp. ist mir unbekannt.

Die Art gehört wegen ihrer zweifachen Behaarung in die Untergattung *Melanotrichus* Reut. und muss dort in die Gruppe der Arten mit sehr einfach gebauten Genitalien (*Halocapsus* Put.) gestellt werden. Sie ist mit *O. minutus* Jak. und *O. schoberiae* Reut. am naechsten verwandt und stimmt mit beiden in der Laenge der Hintertarsen überein, unterscheidet sich aber von ihnen durch grössere Gestalt, das kurze Rostrum, die hellen Membranadern und den Bau der Genitalien des ♂. Bei *O. hirtulus* E. Wagn., dem unsere Art ebenfalls aehnelt, überragt das Rostrum die Hinterhüften, der Scheitel ist

beim ♂ $1,9 \times$ so breit wie das Auge, das 2. Fühlerglied ist $1,2 \times$ so lang wie der Kopf breit ist und die Gestalt ist breiter. Bei *O. palustris* Reut., *O. salsolae* Reut. und *O. schoberiae* Reut. reicht das Rostrum bis zu den Hinterhüften oder noch darüber hinaus.

Ich untersuchte 2 ♂♂ aus Aegypten : Wadi el Tih 3.11.33 an *Haloxylon* 1 ♂ und Wadi Digla 26.9.33 1 ♂ (beide H. Priesner leg.).

H o l o t y p u s in meiner Sammlung, P a r a t y p o i d in der Sammlung H. Priesner

4. *Campylomma impicta* nov. spec

In Gestalt und Grösse den übrigen Arten recht ähnlich. Einfarbig hell, nur an den Beinen schwarze Punkte oder Flecke. Weisslich ockergelb bis weisslich grün. Oberseits mit feiner, heller Behaarung und einzelnen abstehenden, laengeren, braunen Haaren. Matt.

K o p f gewölbt, von gleicher Farbe wie der übrige Körper, Stirnswiele ohne schwarze Zeichnung. Scheitel beim ♂ $1,15-1,20 \times$, beim ♀ $1,9 \times$ so breit wie das rotbraune bis schwarze Auge. Fühler einfarbig hell, mit sehr feiner, dunkler Behaarung, weisslichgelb; 1. Glied sehr kurz, beim ♂ $0,50-0,55 \times$, beim ♀ $0,65 \times$ so lang wie der Scheitel breit ist, dick, mit einzelnen hellen Borsten; 2. Glied beim ♂ stabförmig, verdickt, dicker als beim ♀, beim dünn, gegen die Spitze leicht verdickt, beim ♂ $0,8 \times$, beim ♀ $0,83 \times$ so lang wie der Kopf samt Augen breit ist; 3. Glied $0,6 \times$ so lang wie das 2. und $1,4-1,5 \times$ so lang wie das 4., die beiden Endglieder dünn.

P r o n o t u m breit und kurz, Schwielen undeutlich. Schildgrund frei. Halbdecken einfarbig weisslich, das Abdomen überragend. Membran hell rauchgrau, Adern weisslich.

U n t e r s e i t e von gleicher Faerbung wie die Oberseite. Rostrum hell, die Spitze schwarz, beim ♂ fast die Spitze der Hinterhüften erreichend, beim ♀ die Hinterhüften weit überragend. Beine weisslich gelb, mit sehr feiner, heller Behaarung. Schenkel vor der Spitze mit einzelnen schwarzen Punkten, Hinterschenkel am Hinterrande mit 2 grossen Punkten, am Vorderrande mit einem schwarzen Fleck, der eine Borste traegt. Schienen mit schwarzbraunen Dornen, die aus schwarzen Punkten entspringen; diese Punkte fehlen im distalen Drittel der Vorder- und Mittelschiene. Hinterschiene $2,9-3,0 \times$ so lang wie der Fuss (ohne Klauen). 3. Glied der Hintertarsen etwas kürzer als das 2. Klauen leicht gekrümmt, Haftlaepchen kurz, fast so breit wie lang.

G e n i t a l s e g m e n t des ♂ (Fig. 23) klein, Seiten geschweift, Behaarung verhaeltnismässig lang. Rechter Genitalgriffel (Fig. 24) klein, flach, sehr breit. Hypophysis undeutlich. Linker Griffel (Fig. 25) mit langer, schlanker Hypophysis und kurzem Sinneshoecker, der einen kurzen, stumpfen Zahn traegt. Penis (Fig. 26) klein, stark gekrümmt. Spitze der Vesica (Fig. 27)

mit drei langen, schlanken Chitinspitzen, die kaum divergieren, sekundaere Gonopore weit vor der Spitze. Spitze der Theca (Fig. 28) schlank, proximal stark gekrümmt, distal geschweift, spitz.

Laenge von $\sigma = 2,2-2,4$ mm., $\varphi = 2,3-2,5$ mm.

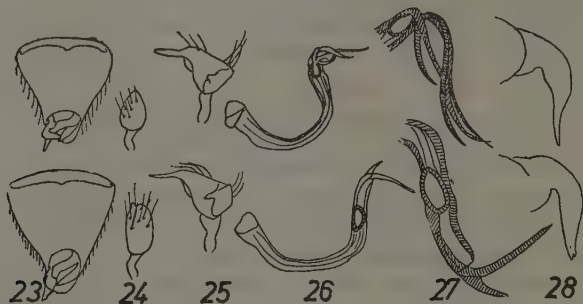


Fig. 23-28 : *Campylomma*, Genitalien des σ :

Fig. 23 : Genitalsegment von oben ($31,5\times$). — Fig. 24 : Rechter Griffel ($84\times$). — Fig. 25 : Linker Griffel ($84\times$). — Fig. 26 : Vesica des Penis ($84\times$). — Fig. 27 : Spitze der Vesica ($168\times$). — Fig. 28 : Spitze der Theca ($84\times$). — Obere Reihe : *C. impicta* nov. spec., untere Reihe : *C. nicolasi* Reut.

C. impicta nov. spec. unterscheidet sich von allen übrigen palaearktischen Arten durch die völlig ungefleckten Fühler und den einfarbig hellen Kopf. *C. nigronasuta* Reut. aus Turkestan hat zwar gleichfalls helle Fühler, aber eine völlig schwarze Stirnswiele. Die neue Art steht *C. nicolasi* Reut. am naechsten, unterscheidet sich aber von ihr durch die hellen Fühler, laengeres Rostrum, kürzere Fühler, laengere Tarsen und den Bau der Genitalien des σ . Bei *C. nicolasi* sind die ersten beiden Fühlerglieder stets schwarz gezeichnet, das Rostrum überragt beim σ kaum die Mittelhüften und erreicht beim φ die Mitte der Hinterhüften, das 1. Fühlerglied ist beim σ $0,75\times$, beim φ $0,87\times$ so lang wie der Scheitel breit ist, das 2. Glied ist mindestens $0,9\times$ so lang wie der Kopf breit ist, das Genitalsegment des σ (Fig. 23) ist grösser, seine Seiten sind nicht geschweift, der rechte Genitalgriffel (Fig. 24) ist laenger, seine Hypophysis deutlich, der linke Griffel (Fig. 25) hat eine schlankere Hypophysis und einen laengeren, spitzeren Zahn auf dem Sinnessoecker. Der Penis (Fig. 26) ist grösser, schlanker und seine Spitze hat 2 ungleich lange, stark divergierende Chitinspitzen (Fig. 27), die Spitze der Theca (Fig. 28) ist distal nicht geschweift und deutlich zweispitzig.

Ich untersuchte 10 σ und 19 φ aus Aegypten : Meadi 7.6.31 1 σ , 2 φ , 12.+13.6.34 3 φ , 27.6.35 1 φ , 26.5.36 1 σ ; Heliopolis 7.7.29 1 φ (H. Priesner leg.); Kafr Hakim 24.6.31 1 σ , 2 φ , und Iran, Belutschisten : Iranshar 28.-31.3.54 1 φ , 1.-10.4.54 2 σ , 1 φ , 11.-21.5.54 5 σ , 8 φ (R i c h-

ter et Schaeuffele leg.).

Holotypus (Mead) und Paratypoiden in meiner Sammlung,
Alloptypoid und Paratypoiden in der Sammlung H. Priesner,
Paratypoiden auch in der Sammlung des Naturkunde-Museums in
Stuttgart.

Ueber einige fuer Aegypten neue oder seltene Orthopteren

(mit 2 Abbildungen)

von R. EBNER, Wein.

Im Laufe der letzten Jahre uebermittelte mir mein Freund Prof. Dr. H. Priesner diverse Orthopteren zur Revision und Determination. Unter dem Material befanden sich mehrere Arten, die zum Teil ueberhaupt recht selten sind und zum Teil sogar fuer Aegypten neu waren. Dadurch wird in allen Faellen unsere Kenntniss namentlich ueber die Verbreitung dieser Arten sehr erweitert, sodass eine Publikation darueber gerechtfertigt erscheint.

Das Material befindet sich zum Teil in staatlichen wissenschaftlichen Sammlungen in Aegypten und zum Teil in meiner Sammlung, wofuer ich Freund Priesner sehr zu Dank verpflichtet bin.

BLATTIDEA

Hololampra (s. lat.) nilotica n. sp.

(Subgenus *Lobolampra* Houlbert 1927, oder *Arbiblatta* Chopard 1936)

Die Unterscheidung der beiden Subgenera ist nur nach dem ♂ moeglich.

Borg El-Arab, 9. iv. 1955. Entomology Dept., Faculty of Science, Ein Shems University, 1♀ (leg. H. Priesner).

Kopf schwaerzlich, zwischen den Augen mit breiter heller Querbinde. Grundfarbe des Koerpers oben hellbraun, ueberall mit feinen dunklen Punkten. Discus des Pronotums braun und vom hellen Rand deutlich abgesetzt, mit 2 dunkleren Flecken in der Mitte des Vorderrandes und mit ebensolchen Punkten. Metanotum etwas laenger und breiter als das Mesonotum, mit dunkleren Flecken, die vom Vorderrand ausgehen. Elytren am Innenrand sehr schwach gebogen und daher fast gerade. Abdominalsegmente am Vorderrand fast schwarz, die dadurch entstehenden Querbinden sind namentlich nahe den Seitenraendern und zum Teil auch in der Mittellinie breiter. Dunkle Zeichnungen der Dorsalseite stellenweise etwas asymmetrisch.

Beine und Cerci ebenfalls gelbbraun, letztere an der Basis dunkler.

Körperlänge (Abdomen etwas gedehnt) 9.7 mm., Pronotum 2.3 mm., Elytren 1.3 mm., grösste Breite des Pronotums 3.5 mm.; grösste Breite des Abdomens 4.5 mm.



Fig. 1 : *Hololampra* (s. lat.) *nilotica* n. sp., ♀.

Durch das in der Mitte ein wenig dunklere Pronotum etwas an *Lobolampra cazurroi* und durch die schwaerzlichen Querbinden des Abdomens etwas an *Lobolampra bolivari* erinnernd, aber von beiden Arten nach Chopard (1943) sicher verschieden.

Das Genus ist auf jeden Fall fuer Aegypten neu. Beide Subgenera sind in Nordwest-Afrika verbreitet und besonders in Marokko durch zahlreiche Arten vertreten; *Lobolampra* wird auch aus Spanien und Portugal genannt. Ferner kommen beide Subgenera in wenigen Arten auch in West- und Zentral-Asien vor (Bey-Bienko, 1950). Meines Wissens ist aber noch kein Vertreter der Gattung *Hololampra* (s. lat.) aus Libyen bekannt geworden. Das vorliegende ♀ stammt also vom oestlichsten Fundort der ganzen Gattung in Nord-Afrika.

Bey-Bienko betrachtet 1938 *Arbiblatta* nur als Subgenus von *Phyllodromica* Fieb. (= *Hololampra* Sauss.), da man die ♀ ♀ vieler Arten nicht von einander unterscheiden kann. Auch 1950 fuehrt er *Arbiblatta* und *Dziriblatta* (= *Lobolampra*) nur als Subgenera von *Phyllodromica* an.

Mareta (?) treitliana (Wern.)

Werner, Sitz. Ak. Wien, math.-naturw. Kl., CXIV, Abt. 1, 1905, p. 377; ibid., CXVI, Abt. 1, 1907, p. 174 (*Phyllodromia*).

Werner, Zool. Jahrb. Syst., XXXIV, 1913, p. 209 (*Phyllodromia*).

Chopard, Ann. Soc. ent. France, CX, 1941, p. 45 (*Mareta*).

Chopard, Mém. Inst. franç. Afr. noire, nr. 10, 1950, p. 129 (*Mareta*).

Kevan und Chopard, Ann. nat. Hist. (12) VII, 1954, p. 176 (*Mareta*).

Kharga, iii. 1932, Priesner, 1♂.

Interocularbinde hellbraun, in der Mitte fast unterbrochen. Unter-

seite des Abdomens fast einfaerbig hell, nur an den Seiten mit kleineren undeutlichen dunkleren Flecken. Auch bei dem Material von Werner, das ich im Wiener Museum gesehen habe, ist die Unterseite des Abdomens seitlich nur mit kleinen dunklen Punkten versehen. Subgenitalplatte des ♂ etwas gekielt, am Ende deutlich eingeschnitten; Styli sehr kurz.

Die Art wird von neueren Autoren zu *Mareta* gestellt, doch erscheint mir die Zugehoerigkeit zu diesem Genus nicht sicher; es kommt eventuell auch das Genus *Margattea* Shelf. in Betracht. Mindestens spricht die Bedornung der Vorderschenkel bei dem vorliegenden ♂ eher fuer *Margattea* (Bolivar 1895, Shelford 1911, Rehn 1931) als fuer *Mareta*.

Die hier besprochene Art wurde aus Unter-Aegypten beschrieben und wird auch von Kenya-Jubaland, Franzoesisch Nigeria, Borkou und Air angegeben.

Heterogamodes kruegeri (Salfi)

Chopard, *Eos*, V, 1929, p. 334.

Chopard, Faune de l'Empire français, I, Orth. Afrique Nord, Paris 1943, p. 50.

Borg El-Arab (Abuseer), 3. vi. 1954, 1♀.

Das mir vorliegende Exemplar wurde bereits von Priesner bestimmt, ich kann seine Determination nur bestaetigen.

Die Art ist neu fuer Aegypten. Aus der Cyrenaika beschrieben und sonst noch von Hoggar und Tassili bekannt.

Seit der Monographie von Chopard ueber die palaearktischen Polyphaginen (1929) sind folgende Arten von *Heterogamodes* neu beschrieben worden :

H. chopardi Uvarov 1936, Arabien; *H. marmorata* Uvarov 1936, Arabien; *H. minuta* Bey-Bienko 1935, Turkmenistan (Diese Art wurde 1950 von Bey-Bienko also *Arenivaga* (*Psammoblatta*) angefuehrt). *H. zavattarii* Salfi 1935, Libyen (Nach Uvarov (1943) auch in den Siwa Oasen); *H. zolotarevskyi* Chopard 1940, Mauretanien.

MANTIDEA

Heteronutarsus aegyptiacus Lef.

Innes, *Mém. Soc. ent. Egypte*, I, fasc. 3, 1912, p. 42 (*Heteronytarsus*).

Giglio-Tos, Tierreich, Lief. 50, 1927, p. 45, 60.

Capra, *Ann. Mus. Storia Nat. Genova*, LIII, 1929, p. 126.

Salfi, *Atti Soc. Ital. Sci. Nat.*, LXXIV, 1935, p. 385.

Gebel Asfar, 11. iv. 1933, leg. Priesner, 2♂♂.

Am 9. ii. 1914 fand ich beim Simonskloster in der Naeh von Assuan mehrere ziemlich grosse Larven dieser Art. Die schnellen und langbeinigen Tiere liefen wie kleine Gespenster auf dem gelblichen Sand und waren nicht leicht zu fangen. Ihre Nahrung musste wohl hier aus kleinen Dipteren

bestehen, welche gelegentlich dort hinkamen; andere eventuell in Betracht kommende Beutetiere sah ich nicht.

Diese anscheinend ziemlich seltene Art ist aus Unter- und Ober- Aegypten, sowie aus Libyen (Cyrenaika, Kufra, Fezzan) bekannt.

Empusa hedenborgi Stael

Uvarov, Ministry of Agriculture, Egypt, Techn. and Sci. Service, Bull. 41, Cairo 1924, p. 5, t. 1, f. 2, 4.

Giglio-Tos, Tierreich, Lief. 50, 1927, p. 636, 640.

Beier, Gen. Ins., fasc. 197, 1934, p. 5.

Bodenheimer, Arch. Naturg. (N. F.), IV, h. 2, 1935, p. 153.

Ramme, Mitteil. zool. Mus. Berlin, XXVII, 1950 (1951), p. 132.

Fayed, Unter-Aegypten, 1942-44, Priesner, 1♂.

Das Exemplar stimmt sehr gut mit den Angaben bei Uvarov ueber Pronotum, Fluegel und Hintercoxen ueberein. Koerperlaenge 70 mm.; Pronotum 28, Elytren 40, Hinterschenkel 18 mm.

Verbreitung der Art : Nubien, Unter-Aegypten, Khartoum, Ost-Afrika, Arabien, Palaestina. Scheint ziemlich selten zu sein und wurde nicht von allen Autoren gleich beschrieben, daher halte ich eine Erwachnung des neuen Fundortes mit einigen Angaben von Interesse.

GRYLLACRIDIDAE

Lezina concolor Walk.

Uvarov, Ministry of Agriculture, Egypt, Techn. and Sci. Service, Bull. 41, Cairo 1924, p. 12, t. 1, f. 16.

Karny, Gen. Ins., fasc. 206, 1937, p. 37.

Fayed, Unter-Aegypten, 1942-44, Priesner, 1♂. Fayed liegt am Bittersee, der den Suezkanal teilt.

Diese seltene Art ist aus Aegypten, Sinai und Ost-Afrika bekannt. Fuehrt eine naechtlche Lebensweise. Die Gattung enthaelt nur wenige Arten; ihr Verbreitungsgebiet umfasst Algerien, Aegypten, Ost-Afrika, Vorder-Asien bis Zentral-Asien.

GRYLLIDAE

Acheta hispanicus Ramb. var.

Kirby, Synon. Cat. Orthopt., II, 1906, p. 28 (*Gryllus*).

Giglio-Tos, Boll. Mus. Torino, XXXVIII (n. s.), nr. 4, p. 7 (*Gryllus*).

Salfi, Arch. Zool. Ital., XIV, 1930, p. 399, Quadro nr. 22 (*Gryllus*).

Salfi, Boll. Zool., I, Napoli, 1930, p. 55 (*Gryllus*).

Chopard, Faune de l'Empire français, I, Orth. Afrique Nord, Paris 1943, pp. 181-182 (*Gryllulus*).

Morales Agacino, Eos, XX, 1944, p. 321 (*Gryllulus*).

Chopard, Bull. Soc. Sc. nat. Maroc, XXV-XXVII, 1945-47 (1948), p. 193 (*Gryllulus*).

Kena, 1. ii. 1952, Ober-Aegypten. Entomology Dept., Faculty of Science, Ein Shems, University, 1♀.

Unterscheidet sich von typischen Exemplaren, die ich im Wiener Museum gesehen habe, durch die etwas breitere gelbe Querbinde zwischen den Ocellen. Pronotum fast einfaerbig schwarzbraun, nur an den Seitenkanten und an den unteren Raendern etwas aufgehellt. Elytren etwas kuerzer als das Abdomen.



Fig. 2 : *Acheta hispanicus* Ramb. var. ♀ : Kopf von vorne.

Koerperlaenge 18 mm., Pronotum 3.5 mm., Elytren 10.5 mm., Fluegel 15.5 mm., vorragender Teil der Fluegel 6 mm., Hinterschenkel 10.5 mm., Ovipositor 10 mm.

Verbreitung von *A. hispanicus* : Spanien, Tenerife, Madeira, westliche Sahara, Ifni, 3 Atlas-Laender, Sizilien, Bengasi, Barka. Die Art war aus Aegypten noch nicht bekannt. Nach Chopard in der mediterranen Region.

Es waere vielleicht auch an *Gryllus tartarus obscurior* Uvar. 1934 zu denken, der in West-Asien weit verbreitet ist.

Eugryllodes mareoticus (Wern.) ?

Werner, Sitz. Ak. Wien, math.-naturw. kl., CXIV, 1, 1905, p. 434 (*Gryllodes*).

Balteem, 2. viii. 1945. Entomology Dept., Faculty of Science, Ein Shems University, 1♀. Mediterran, bei Alexandrien.

Zum Vergleich stand mir nur 1 paratypisches ♀ (ohne Vorderbeine) aus meiner Sammlung mit den Angaben : Alexandrien (Mex), 26. iv. 1905, leg. et det. Werner zur Verfuegung.

Nur mit Zweifel stelle ich das vorliegende Exemplar hieher, da es namentlich in der Faerbung ziemlich stark abweicht. Es ist viel heller als die Paratype; fast einfaerbig gelbbraun, aber doch mit den Andeutungen der von Werner angegebenen Zeichnungen. Clypeo-faciale Sutura ganz wenig tiefer als die Mitte der Fuehlergruben, bei der Paratype deutlich bis zu deren Mitte reichend. Pronotum namentlich am Vorder- und Hinterrand deutlich dunkel behaart. Das innere Tympanum der Vordertibien ist nur durch eine

leichte Erhöhung angedeutet. Hintertibien innen mit 4-5 Dornen, der oberste sehr klein; bei der Paratype innen mit 5 Dornen.

	Paratype	♀ aus Balteem
Körperlaenge	10 mm.	9 mm.
Pronotum	2 mm.	2 mm.
Elytren	4 mm.	3.5 mm.
Hinterschenkel	6 mm.	5.5 mm.
Hintertibia	4.2 mm.	4 mm.
Metatarsus	1.8 mm.	1.5 mm.
Ovipositor	6.5 mm.	6.5 mm.

Chopard hat kuerzlich auf die Schwierigkeiten in der Unterscheidung mancher Gattungen von Grylliden hingewiesen (*Ann. Mus. Congo, Tervuren, Zool.*, 1, 1954; *Miscell. Zool.*, pp. 326-328). Werner gibt nach der Beschreibung von *Grylloides mareoticus* an, dass die Art nach dem Fehlen des inneren Tympanums an den Vordertibien und nach der Faerbung zu *Grylloides*, dagegen wegen der rhombischen Retikulation der Elytren des ♀ zu *Gryllus* zu rechnen ist.

Stimmt sonst mit keiner der beschriebenen Arten von *Grylloides* (s. lat.) und *Gryllus* (= *Acheta*) ueberein, soweit diese aus zoogeographischen Gruenden hier nur etwas in Betracht kommen.

***Pteronemobius hafferli* (Wern.)**

Werner, *Sitz. Ak. Wien, math. - naturw. Kl.*, CXIV, Abt. 1, 1905, p. 433 (*Nemobius*)
Uvarov, Ministry of Agriculture, Egypt, Techn. and Sci. Service, Bull. XLI, Cairo 1924, p. 15.

Mead, 15. vi. 1930, Priesner, 1 macropteres ♂.

Luxor, 25. i. 1954, Entomology Dept., Faculty of Science, Ein Shems University, 1♂ 2♀♀, alle 3 Exemplare brachypter.

Wurde 1905 von Werner als *Nemobius* nach einem brachypteren ♀ aus der Umgebung des ersten Kataraktes beschrieben. Ich habe die Type im Wiener Museum nicht finden koennen. 1924 fuehrt Uvarov die Art von Mead an; sein Exemplar, ebenfalls 1 brachypteres ♀, war etwas defekt, weshalb er seinen Determinationsnamen mit einem "?" versehen hatte. Neu sind sowohl die ♂♂ als auch die macroptere Form.

Bei den Exemplaren von Luxor erreichen die Elytren beim ♂ das Ende des Abdomens, bei den ♀♀ bleibt das Abdomen-Ende ganz frei. Hinterfluegel bei diesen Tieren nicht sichtbar. Ovipositor gerade. Bei dem macropteren ♂ betraegt die Laenge der Hinterfluegel 8 mm., ihr vorstehender Teil ist 5 mm. lang.

Ausser den zwei Zitaten kenne ich keine weiteren Angaben in der Literatur ueber diese Art. Sie stimmt weitgehend mit *Pterohemobius occidentalis*

Chop. 1936, 1941 und 1943 (Marokko, Hoggar) ueberein und ist vielleicht damit sogar identisch; ich kenne auch diese Art nur nach der Beschreibung.

Myrmecophilus cottami Chop. var. robustus nov.

Chopard, Bull. Soc. ent. France, 1922, p. 42 (*cottami*) ; *ibid.*, 1923, p. 29 (*cottami*).
Capra, Ann. Mus. Genova, LIII, 1929, p. 138 (*americana*).

Cairo, bei *Camponotus*, Priesner, 1♂.

Abu Mena (Landschaft Marjût), 8. iv. 1954, Entomology Dept., Faculty of Science, Ein Shems University, 1♀.

Im allgemeinen mit *cottami* uebereinstimmend, aber viel grösser und namentlich breiter; besonders das Pronotum ist sehr gross und hinten sehr breit. Ist gewiss weder *acervorum* noch *ochraceus*. Faerbung beider Geschlechter gleich. Ohne helle Laengslinie am Ruecken, Cerci sehr dunkelbraun. Pronotum beim ♂ veil breiter als beim ♀. Ovipositor etwas abweichend von der Zeichnung bei Chopard. Körperlaenge ♂ 2,4mm., Laenge des Pronotums 1 mm, Breite des Pronotums 1,8 mm.

Type der neuen Form : ♂ in meiner Sammlung. — Das ♀ liegt mir derzeit nicht mehr vor, doch hatte ich mir fruher einige Notizen gemacht, bevor ich es zurueck gegeben hatte.

Die Nominatform wurde 1922 aus Khartoum beschrieben, wo sie bei *Prenolepis longicornis* Latr. gefunden wurde. Aber 1923 schreibt Chopard selbst, dass *cottami* mit der weit verbreiteten Art *Myrmecophila americana* Sauss. identisch sein koennte. 1929 nennt Capra die Art aus der Cyrenaika und bezeichnet sie in Uebereinstimmung mit Chopard als *americana*.

Das Genus ist auf jeden Fall fuer Aegypten neu und auch der Wirt *Camponotus* ist sehr interessant.

Die im Vergleich zur Nominatform bedeutende Grösse haengt vielleicht mit den verschiedenen Wirtsameisen zusammen, denn aehnliche Beobachtungen wurden auch an *Myrm. acervorum* gemacht. Daher habe ich die neue Form derzeit nur als "var." bezeichnet. Weitere Funde waeren sehr wuensenswert, um zu entscheiden, ob nicht vielleicht ueberhaupt eine neue Art vorliegt.

TETTIGONIDAE

Steropleurus innocentii Bonnet und Finot

Ebner, Orthopt. Catal., I, 1938, p. 21, ♂♀ (*Uromenus*).

Chopard, Faune de l'Empire français, I, Orth. Afrique Nord., Paris 1943, p. 144, 146, f. 229, 231, 232 i, ♂♀.

Morales Agacino, Eos, XX, 1944, p. 319, t. 22, f. C, ♂♀.

Mersa Matrouh (Nordwest-Aegypten), 1 Exemplar, Entom. Dept., Cairo University. Nach Angaben und Bestimmung von Priesner. Ich

habe das Tier nicht gesehen, doch hat es Priesner nach dem Werk von Chopard determiniert.

Bisher bekannte Verbreitung der Art : Tunesien, Algerien, Marokko, Rio de Oro.

Die Subfamilie *Ephippigerinae* hat ihr Hauptverbreitungsgebiet in Suedwest-Europa und Nordwest-Afrika, sie reicht nach den bisherigen Angaben in Afrika mit der Gattung *Steropleurus* östlich bis in die Marmarica (Salfi 1935). Daher ist die Subfamilie fuer Aegypten neu.

Anepisceptus horridus (Burm.)

Ebner, Orthopt. Catal., II, 1938, p. 83, ♂♀.

Weidner, Zool. Anz., CXXXIV, 1941, p. 289, ♂♀.

Gebel Elba (nahe der Suedost-Grenze von Aegypten), South Eastern Desert, iv.-v. 1929, 1♀, Zool. Dept. Collection, Cairo University, leg. Tewfik.

Aus einer Serie vom Gebel Elba liegt mir das oben genannte Exemplar vor. Es ist sehr erfreulich, dass wir damit wieder einen genauen Fundort aus neuerer Zeit fuer diese Art erhalten haben.

Die Verbreitungsangaben dieser Art lauten : Syrien, Aegypten, Ras Benas am Roten Meer (ca. 24° noerdl. Breite), Arabien, Eritrea, Somaliland.

TRIDACTYLIDAE

Tridactylus fasciatus Guér. (= savignyi Guér.)

Werner, Sitz. Ak. Wien, math.-naturw. Kl., CXIV, Abt. 1, 1905, p. 431.

Werner, Denkschr. Ak. Wien, math.-naturw. Kl., CI, 1927, p. 77, 78.

Asswan (Kitchener Insel), 6.iii.1931, Priesner, 1 helles und kleines Exemplar.

T. savignyi ist nur eine dunkle Farbenvarietaet, die mit der typischen Form (= *fasciatus*) durch viele Uebergaenge verbunden ist.

Verbreitungsangaben von *fasciatus* : Aegypten, Ost-Afrika, Indien, China; fuer *savignyi* : Aegypten, Sued-Russland, West- und Zentral-Asien.

Im Wiener Museum sah ich ein Exemplar von der Insel Elephantine bei Asswan (Assuan, Assouan). Werner gibt wiederholt an, dass auf Elephantine *T. savignyi*, auf Atrun (Kitchener Insel) *Trid. variegatus* (Latr.) vorkommt; er spricht direkt von einem vikariierenden Vorkommen der beiden Arten auf den zwei Inseln. Dieser Ansicht kann ich mich nicht anschliessen, denn ich fand auf Elephantine (8.ii.1914) und bei Shellal (7.ii.1914) nur *T. variegatus*. Auf der Kitchener Insel (9.ii.1914) habe ich selbst keinen *Tridactylus* gesehen. Es kommen also beide Arten auf beiden Inseln vor.

ACRIDIDAE

Eremogryllus hammadae Krauss

Uvarov und Volkonsky, *Proc. ent. Soc. London*, XIV, 1939, p. 19-23.
Chopard, Faune de l'Empire français, I, Orth. Afrique Nord, Paris 1943, p. 281.
Morales Agacino, *Eos*, XX, 1944, p. 326; *ibid.*, 23, 1947, p. 264.

Kom Osheem (Landschaft Faijûm), 4.iv.1953, Entomology Dept., Faculty of Science, Ein Shems University, 1♀.

Das vorliegende Exemplar unterscheidet sich von Stuecken, die ich am 12.v.1930 zwischen Berguent und Tendirara in Ost-Marokko gefangen hatte, durch eine unscheinbare, hell-graubraune Faerbung fast ohne Fleckenzeichnung und durch etwas geringere Grösse. Die sehr charakteristische Pronotumzeichnung und die fehlenden Arolen (Krallenpelotten) lassen die Art leicht erkennen. Stridulation wie bei einer Grille. Sehr bemerkenswert ist ferner das Eingraben, wodurch die Tiere schwer zu sehen sind.

Das Genus ist neu fuer Aegypten. Sonstige Verbreitung der Art : westliche Sahara, Marokko, Algerien, Tunesien, Tripolitanien.

Scintharista notabilis lateritia Uvar.

Uvarov, *Proc. ent. Soc. London* (B), X, 1941, p. 92, 94.
Kevan, *Ann. Mag. Nat. Hist.* (12), IV, 1951, p. 718.

Gebel Elba, Egypt, Wadi Aideb, ii, Priesner, 1♂.

Die Art *Scintharista notabilis* (Walk.) reicht von den Canaren bis Nordwest-Indien und wird in mehrere Subspecies zerlegt, sie ist aus Aegypten noch nicht mit Sicherheit bekannt. Bisher bekannte Verbreitung der Subspecies *lateritia* : Anglo-Aegyptischer Sudan, Eritrea, Somaliland; der Gebel Elba ist daher der nördlichste Fundort dieser Rasse.

Der Gebel Elba liegt an der äussersten Südost-Ecke von Aegypten, also an der Sudangrenze, bloss 40 km. vom Roten Meer. Faunistisch ist er zu der Subregion der nubischen Berge zu rechnen.

Acrotylus longipes (Charp.)

Innes, *Mém. Soc. ent. Egypte*, III, fasc. 2, 1929, p. 46.
Bey-Bienko und Mistshenko: Heuschreckenfauna der SSSR und der angrenzenden Länder, II, Moskwa u. Leningrad 1951, p. 597 (russisch).

Gebel Elba, Wadi Aideb, 27.-28.ii.1938, Priesner, 1♂.

Hinterflügel fast ganz farblos, nur an der Basis sehr leicht hellrosa.

Verbreitung der Art. : Süd-Europa, grosse Teile von Afrika, West-Asien. Scheint in Aegypten recht selten zu sein, Innes nennt das Tier nur von Edfou in Ober-Aegypten.

***Tmethis pulchripennis pulchripennis* (Serv.)**

U v a r o v, *Trans. ent. Soc. London*, LXXXIII, 1943, p. 66.

Ch o p a r d, *Faune de l'Empire français*, I, Orth. Afrique Nord, Paris 1943, p. 332.

Cairo, P r i e s n e r, 1♀.

Hierher stelle ich am ehesten nach U v a r o v das Exemplar, bei dem namentlich das Abdomen etwas geschrumpft ist. Fluegel bis auf die dunkle Binde fast farblos. Hintertibien aussen hell-graubraun, innen roetlich, oben zum Teil etwas blaeulich. An den Hinterbeinen ist der zweite Pulvillus aber eher wie bei *T. cisti* (Fabr.) beschaffen.

Nach U v a r o v die einzige echte *Tmethis*-Art aus Aegypten und nur von dort bekannt.

***Calliptamus barbarus deserticola* Voss.**

Ch o p a r d, *Faune de l'Empire français*, I, Orth. Afrique Nord, Paris 1943, p. 404.

R a m m e, *Mitt. zool. Mus. Berlin*, XXVII, 1950 (1951), p. 312.

M i s t s h e n k o, *Faune SSSR*, IV, 2, Moskwa u. Leningrad 1952, p. 544 (*barbarus cephalotes* F.-W.) (russisch).

M e a d i (14 km. suedlich von Cairo), viii. 1931, P r i e s n e r, 1♀

I n n e s (1929, p. 150-152) gibt an, dass *C. italicus* (L.) in der Umgebung von Cairo sehr haeufig ist; er fuehrt unter den Synonymen von *italicus* auch *barbarus* (Costa) an. R a m m e nennt *deserticola* von Nord-Afrika, West- und Zentral-Asien. Immerhin haben wir mit dem genannten Exemplar einen sicheren Fundort von *barbarus deserticola* aus Aegypten.

DERMAPTERA***Forficula lucasi* Dohrn (=barroisi Bol.)**

B u r r, *Gen. Ins.*, fasc. 122, 1911, p. 81.

I n n e s, *Mém. Soc. ent. Egypte*, I, fasc. 3, 1912, p. 14-15.

B e y - B i e n k o, *Faune de l'URSS* (N.S.), nr. 5, Moscou und Leningrad 1936, p. 135, 224.

S e m e n o v - T i a n - S h a n s k i j, *Eos*, XIV, 1938 (1940), p. 64.

Ch o p a r d, *Faune de l'Empire français*, I, Orth. Afrique Nord, Paris 1943, p. 424.

Gebel Elba, 1.ii.1933 A., leg. P r i e s n e r, 2♂♂ 3♀♀.

Gebel Elba, Halaib, 8.ii.1933, leg. P r i e s n e r, 1♀.

Elytren im Basalteil mit grossem gelbbraunem Fleck; Fluegelschuppe meist ebenfalls gelbbraun und meist gross, nur bei 1♀ vom erstgenannten Fundort viel kuerzer als bei allen anderen Exemplaren. Die beiden ♂♂ sind sehr ungleich gross.

Koerperlaenge (ohne Zange) : ♂, 11.5, 14.5 mm.; ♀, 12.5-13.5 mm.

Zänge : ♂, 4.5, 7 mm.; ♀, 3.5 mm.

Verbreitung der Art : Nord-Afrika und West-Asien.

Manche Autoren vereinigen die beiden oben genannten Arten und manche trennen sie; ich bin fuer die Vereinigung.

Further additions to the knowledge of some leaf-miners from Egypt

[Lepidoptera and Diptera]

R

(with 2 Text-Figures)

by S. M. HAMMAD, Ph. D.,
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In previous papers (Hammad, 1955, and Hammad and Deeb) five leaf-miners have been recorded from the Alexandria vicinity. The present paper includes eight more leaf-miners, of which four lepidopterous and four dipterous ones, which were obtained from the Alexandria University Agricultural Experiment Farm during April, 1954. It is hoped that the present contribution will add to our knowledge of the insect pests of Egypt.

Lepidoptera

1. *Acrocercops conflua* Meyrick (Gracilariidae).

Host plant : Castor Oil (*Ricinus communis* L.).

Nature of damage : Linear blotch mine silvery-white in colour (Fig. 1A). The damage occurs on the upper surface of the leaf on any part of the blade. Main rib mostly not affected, but other secondary veins attacked. All tissues between upper and lower epidermis of the leaf are eaten by the mining larva. Larval frass deposited in the mine channel as shown in Figure 1B. Pupation takes place inside the mine.

This tiny Gracilariid moth was described in 1914, from Natal (South Africa) without any designation of its host plant. It has been recorded from Egypt (Willcocks 1922) under the name of the Castor Leaf-Miner (*Gracilaria* spec.), Palestine (Amsel and Hering 1931), and from the North of the Caucasus. It is usually very common where it occurs. I have seen in Alfieri's collection two samples identified by Meyrick in 1925, and labelled "emerged 29.10.1918 from Castor Oil leaves collected

in the garden of the Agricultural Society's laboratory garden, at Ghezireh (Cairo)".

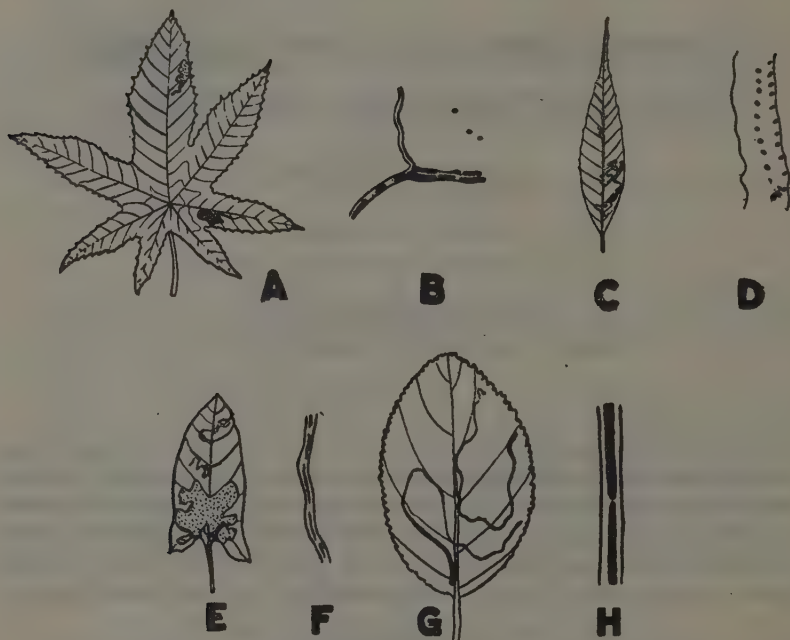


Fig. 1 : (A) Linear blotch mine of *Acrocercops conflua* on leaf of *Ricinus communis*, $\times 0.25$; (B) disposal of larval frass in the mine of same, $\times 3$; (C) linear mine of *Phyllocnistis saligna* on leaf of *Salix tetrasperma*, $\times 0.25$; (D) disposal of larval frass in mine of same, $\times 3$; (E) linear blotch mine of *Bedellia somnulentella* Z. on leaf of *Convolvulus arvensis*; (F) disposal of larval frass in mine of same; (G) linear mine of *Lyonetia clerkella* on leaf of *Pyrus malus*; (H) disposal of larval frass in mine of same.

2. *Phyllocnistis saligna* Zeller (Phyllocnistidae).

Host tree: Willow (*Salix tetrasperma* Roxb.).

Nature of damage: Mine linear and silvery-white in colour (Fig. 1C). Attack occurs on upper and lower surfaces of the leaf. Mine starts at any part of any leaf with a short gallery, and changes in the stem cortex, finally migrating to another leaf. Midrib and other veins are attacked. Larvae feed on the epidermal cells of the leaf and mine in the parenchyma of the stem cortex. Larval frass is deposited in distinct, well separated grains on both sides of the mine channel and at the same time arranged simultaneously (Fig. 1D). Pupation takes place inside the mine.

A species previously recorded from Egypt (Willcocks, 1922), but only under the name of the Sinuous Leaf-Miner of Willow (*Tineidae*).

3. *Bedellia somnulentella* Z. (Lithocolletidae).

Host plant : Lesser blindweed, corn blind, corn lily (*Convolvulus arvensis* L.).

Nature of damage : Linear blotch mine (Fig. 1E), and silvery-white in colour. Infestation occurs on both the upper and underside of the leaf on any part of the blade. The mid-rib and other leaf veins are also attacked. Larvae feed on all tissues between upper and lower epidermis of the leaf, and pupate inside the mine. Arrangement of larval frass in the linear part of the mine is shown in Figure 1 F. In the blotch part, the larva ruptures the mine to throw its frass to the outside. This frass is then found entangled in the web which is spun between the mined leaves. As Hering (1951) stated, there is no explanation for such habit. However, this particularity makes identification easier.

This species has been recorded from Egypt by Willcocks (1922). It has a wide geographical distribution, but it seems that its larvae mines exclusively the leaves of the Convolvulaceae.

4. *Lyonetia clerkella* L. (Lyonetiidae).

Host plants : Frequent on apple (*Pyrus malus* L.), plum (*Prunus triflora*), quince (*Cydonia oblonga* Mill.), and rose (*Rosa* spp.); it is very rare on pear (*Pyrus communis* L.).

Nature of damage : Linear mine (Fig. 1G.), silvery-white in colour and then becomes patched with rusty-brown. Infestation occurs on the upper side of the leaf, on any part of the blade. The mine channel frequently crosses the mid-rib and other veins, even when the larva is in its first instar. Larvae feed on all tissues between upper and lower epidermis of the leaf, and pupate outside the mine. Larval frass is deposited in a more or less continuous line in the middle of the mine channel as shown in Figure 1H.

Hering (1951) stated that *L. clerkella* mines on numerous genera of Rosaceae (and on *Betula*, *Custanea*, and *Salix*), and that within the Rosaceae there are certain species, such as the American *Prunus serotina* Ehrh., on which a large number of mines of this markedly oligophagous species fail to develop normally beyond their early stages. Hering also stated that this species appears in great number in some years, so that on some trees not a single leaf can be found without a mine; in the following year it may be so scarce that no mines can be found.

In a personal correspondence, Prof. Hering states that this leaf miner

is a frequent pest in Europe, but more frequent on *Prunus* than on *Pyrus*. He also says that the infestation of both Rosaceae and *Betula* by *L. clerkella* is a state-piece for the assertion of a proof of the relationship between Rosaceae and Amentaceae.

Stary (1938), as stated by Hering, pointed out that the larvae of *L. clerkella* are rarely attacked by parasitic Hymenoptera, but frequently succumb to "muscardine" disease which is caused by the fungus *Botrytis* spec.

The Apricot Leaf-webber or Webworm (*Recurvaria* spec.) from apricot and peach, the Blister Leaf-Miner (*Tineid*) from pear and quince, and the Rose leaf-miner (*Nepticula* spec.), all recorded from Egypt by Willcocks (1922), may probably refer to *Lyonetia clerkella* L., which is here recorded for the first time from Egypt.

Diptera

5. *Agromyza salicifolii* Collin (Agromyzidae)

Host trees : Willow (*Salix tetrasperma* Roxb.), and Black Poplar (*Populus nigra* L.)

Nature of damage : Linear blotch mine, light green in colour (Fig. 2A). Attack occurs on the upper surface of the leaf. Mine starts on any part of the blade, and is very well characterised by the curious long slit to be found on the leaf at the oviposition site. Midrib is not touched, but other secondary veins are attacked. Larvae feed on all tissues lying between the upper and the lower epidermis of the leaf. Larval frass deposited in a sizeable patch in the centre of the mine as shown in Figure 2B. Pupation takes place outside the mine.

This species, the Willow Blister Leaf-Miner, has been recorded from Egypt by Willcocks (1922) without any mention of the host-tree from which it was bred. It has been also bred by Prof. Hering long ago in the Canary Islands, from *Salix canariensis* Chr. Sm., and was also found by Prof. F. S. Bodenheimer in Palestine on Poplar.

6. *Agromyza graminicola* Hendel (Agromyzidae).

Host plant : Common reed, ditch reed (*Arundo donax* L.).

Nature of damage : Blotch mine, yellowish-green in colour (Fig. 2C). Attack occurs on upper and lower surfaces of the leaf. Mine starts on any part of the blade and it may extend on the leaf-sheath (petiole). Midrib and other veins are attacked. Larvae feed between the upper and the lower epidermis of the leaf. Larval frass deposited in the mine channel as shown in Figure 2D. Pupation takes place outside the mine.

This is the first Egyptian record concerning this species, which seems

to prefer dry sites. It was also bred by Prof. Hering in the South of Spain, again from *Arundo donax*. In Central and North Europe its larva lives in *Phragmites communis* Trin. On the other hand, it appears to be more frequent in the Southern countries than in Central Europe.

7. *Tylomyza pinguis* Fallen (Agromyzidae).

Host plant : Lettuce (*Lactuca sativa* L.).

Nature of damage : Linear mine, silvery-white in colour (Fig. 2E). Attack occurs on the dorsal and the ventral sides of the leaf. Mine starts mostly near the base of the leaf-blade. Midrib and other secondary veins are attacked. Larvae feed on all tissues between upper and lower

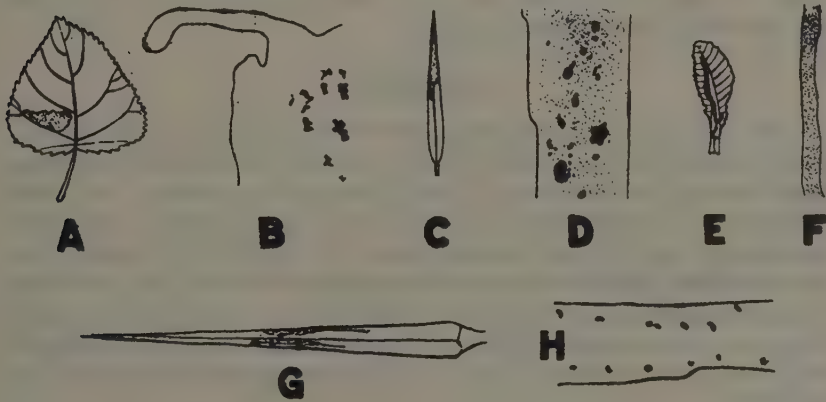


Fig. 2 : (A) Linear blotch mine of *Agromyza salicifolii* on leaf of *Populus nigra*, $\times 0.25$; (B) disposal of larval frass in mine of same, $\times 3$; (C) blotch mine of *Agromyza graminicola* on leaf of *Arundo donax*, $\times 0.25$; (D) disposal of larval frass in mine of same $\times 3$; (E) linear mine of *Tylomyza pinguis* on *Lactuca sativa*, $\times 0.25$; (F) disposal of larval frass in mine of same, $\times 3$; (G) linear mine of *Pseudonapomyza atra* Meigen on *Triticum vulgare*; (H) disposal of larval frass in mine of same.

epidermis of the leaf. The grains of the larval frass are very fine and distributed over the whole width of the mine channel (Fig. 2F). Pupation takes place inside the midrib, towards the base of the blade.

This species is here recorded for the first time from Egypt. It is widely distributed, and occurs often in Europe. It is a pest on the wild chicory (*Cichorium intybus* L.), although it is also found on other wild plants. Mensil (1934) has described the biology as well as the morphology of its different stages. Its occurrence on *Lactuca* was never recorded before.

8. *Pseudonapomyza atra* Meigen (Agromyzidae).

Host plants : Maize (*Zea mays* L.), common wheat (*Triticum vulgare* Vill. and *Triticum pyramidale*), and common barley *Hordeum vulgare* L.).

Nature of damage : Linear mine (Fig. 2G), and silvery-white in colour; in *Zea mays* L., it becomes patched with a rusty-brown colour. It occurs on both the upper and underside of the leaf on any part of the blade; sometimes, mine extends on to the leaf-sheath (petiole). The mid-rib and other veins are also attacked. Larvae feed on all tissues between upper and lower epidermis of the leaf, and pupate outside the mine. Arrangement of larval frass in the mine channel is shown in Figure 2 H.

This leaf-miner was unrecorded from Egypt up to the present. It is common in Europe, where it lives on wild grasses and other gramineous plants. Its pupa differs from that of all other Agromyzidae, for it is beset with numerous little styliiform papillae.

SUMMARY

Four lepidopterous leaf-miner are recorded from the Alexandria vicinity. *Lyonetia clerkella* L. is the first Egyptian record for this species. *Acrocercops conflua* Meyrick and *Phyllocnistis salina* Zeller are the names of two species previously unidentified in the Country. *Bedellia sommulentella* Z. mines exclusively the leaves of the Convolvulaceae. As to the four dipterous leaf-miners recorded, the host trees of *Agromyza salicifolii* Collin are fully mentioned. *Agromyza graminicola* Handel, *Tolomyza pinguis* Fallen, and *Pseudonapomyza atra* Meigen are new records for Egypt. The characteristics of their mines, as well as the disposal of their frass in their mine channels, are described and illustrated.

ACKNOWLEDGMENTS

I wish to express my gratitude to the help offered to me by Prof. Dr. E.M. Hering through personal correspondance. He has also been kind enough to identify all the specimens dealt with in this paper. Thanks are also due to Mr. A. Alfieri for his advice and help offered during the course of this work.

REFERENCES

- Amsel, H. G., and Hering, M. (1931) : Beitrag zur Kenntnis der Minenfauna Palaestinas (*Deutsche Ent. Zeits.*, pp. 113-152).
 Hammad, S. M. (1955) : On some Dipterous leaf-miners from Egypt (*Bull. Soc. Ent. Egypte*, XXXIX, pp. 391-394).
 Hammad, S. M., and El-Deeb, A. L. (1955) : The morphology of

three weevil larvae from Egypt (*Bull. Soc. Ent. Egypte*, XXXIX, pp. 385-389).

Hering, E. M. (1950) : Biology of the leaf-miners.

Mensil, L. (1934) : *Ophiomyia pinguis* Fallen, nuisible aux Endives (*Bull. Soc. Ent. France*, XXXIX, pp. 131-136).

Meyrick, E. (1914) : *Ann. Transvaal Mus.*, IV, p. 201).

Willcocks, F. C. (1922) : A Survey of the more important economic Insects and Mites of Egypt (*Bull. Sult. Agric. Soc.*, Tech. Sect., No. 1, Cairo).



Some factors affecting the longevity,
oviposition, and rate of development
in the Southern Cowpea Weevil,
Callosobruchus maculatus F.

[Coleoptera : Bruchidae]

(with 1 Text-Figure, and 9 Tables)

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I. INTRODUCTION

The Cowpea, *Vigna sinensis* Endl., is one of the most important hay-crops; its seed is a principal leguminous food for human consumption in many parts of the world. According to the 1944-48 statistics of the Egyptian Ministry of Agriculture, an area of 4809, 4151, 4011, and 4260 acres has been respectively cultivated with cowpeas or "lubia" as it is called in arabic. This crop is likely to be more extensively cultivated in Egypt in the near future

owing to the new agricultural policy of increasing the areas allocated for vegetable crops.

Unfortunately, wherever cowpeas are cultivated, the seed is subject to very severe attacks by the Bruchid beetle commonly known as the southern cowpea weevil, the cowpea Bruchid, or the four-spotted bean or cowpea weevil. Bridwell (1929) claimed that the proper technical name for this Bruchid is *Callosobruchus maculatus* Fabricius. But, a great deal of nomenclatorial confusion is included in the literature dealing with it. The specific name "maculatus" has been substituted by several others, although most of the references treated it as "*quadrinaculatus*", under the generic name of *Bruchus*, *Mylabris*, *Laria*, and *Pachymerus*. According to Larson and Fisher (1938), the following list has been furnished by J. C. Bridwell to show the synonymies :

Bruchus maculatus Fabricius, 1775; *Bruchus 4-maculatus* Fabricius, 1792; *Bruchus barbicornis* Fabricius, 1801; *Bruchus bistriatus* Fabricius, 1801; *Bruchus chinensis* Thunberg, 1816 (not *Curculio chinensis* Linné, 1758); *Bruchus longicornis* Thunberg, 1816; *Bruchus litteratus* Schoenherr, 1833; *Mylabris quadrinaculatus* (Fabricius) Baudi, 1887; *Laria quadrinaculata* (Fabricius) Bedel, 1901; *Pachymerus quadrinaculatus* (Fabricius) Schilsky, 1905.

The specific name "maculatus", being the first described, should then be used. Basing our judgement on sound morphological grounds (pronotum conical, its sides straight or a little concave; the pygidium oblique in the female, sub-vertical in the male; the hind femora flattened beneath and longitudinally bicarinate, each carina bearing a tooth near apex, the outer triangular, the inner more acute), the generic name should, therefore, be *Callosobruchus*.

A survey of the literature reveals that the southern cowpea weevil, *Callosobruchus maculatus* F., is known to be occurring long ago in many parts of the world. At the present time there is every reason to believe that this Bruchid has, through the channels of commerce, become of world-wide distribution. However, it can safely be stated that it occurs wherever cowpeas are grown or stored extensively.

The larvae of this Bruchid feed inside the seeds, gradually rendering them unsuitable for planting and unfit for human consumption. Although blackeyed cowpeas are the most favoured seeds to the southern cowpea weevil, yet a great many other varieties of cowpeas, peas and beans are liable to its attack and furnish suitable breeding sources for it. The following is a list of the seeds from which Larson and Fisher (1938) had bred this insect repeatedly for many generations: 20 varieties of cowpeas (*Vigna sinensis*), 9 varieties of soyabeans (*Soja max*), 10 varieties of garden peas (*Pisum sativum*), yard long or asparagus beans (*Vigna sesquipedalis*), *Cajanus indicus*, lentils (*Lens esculenta*), chick peas (*Cicer arietinum*), *Lathyrus sativus* and *L. clymenum*, 2 different

strains of bitter vetch (*Vicia ervilia*), broad beans and small windsor beans (*Vicia faba*), 3 varieties of adzuki beans (*Phaseolus angularis*), mung beans (*P. aureus*), urd beans (*P. aconitifolius*), and 2 varieties of hyacinth beans (*Dolichos lablab*).

The southern cowpea weevil does not confine its attack to cowpeas in storage, but also lays its eggs on the exterior of ripening pods in the field and on seeds in split-pods as well. The adult beetle is a fairly strong flier and will fly from weevily seeds in storage, from neglected small lots of cowpeas in warehouses or farms, or from cowpeas remaining in straw-stacks, to the fields where it causes pre-harvest infestation.

In spite of its great economic importance, the southern cowpea weevil, *Callosobruchus maculatus* F., has been subject to study by a relatively few number of workers. Among those who contributed to its biology are Breitenbecher (1926), Larson (1927), Larson and Fisher (1924 and 1938), Larson and Simmons (1923), and Schoof (1941).

Although different phases of the life-history of this Bruchid were studied, yet many other important factors that affect its biology have been neglected by most workers. This made the writer believe that a contribution towards more through understanding of the life processes, under different conditions, of this widespread and destructive species might be appreciated.

The present work deals with a detailed study of some of the factors believed to affect the adult life-span, oviposition, and the duration of the developmental stages of the southern cowpea weevil, *Callosobruchus maculatus* F. The above mentioned biological variables are all related to the rate of increase, thus playing an important role not only in the economy of the species but also in its combating. The factors investigated in this work are : temperatures and humidities acting during either the adult life or the immature stages, food available during the larval stages, density of population, mating and parthenogenesis, and oviposition site. Assessing the damage caused to cowpeas in storage and the determination of the annual number of generations under weather conditions prevailing in Egypt are also dealt with.

II. MATERIAL AND TECHNIQUE

The original material from which the stock cultures of *Callosobruchus maculatus* were started was infested cowpeas brought from a farm at El-Mataana, Upper Egypt, on September, 1951. On emergence of adults, ten male-female pairs of the newly-emerged beetles were put in each of 8 one-pound glass jars half-filled with blackeyed cowpeas. This has been found to prevent crowding during development which was observed to affect the size of the resultant adults. The jars were covered with muslin secured by rubber

bands, and were put in a large desiccator maintained at a constant relative humidity of 75%. The desiccator was then introduced in an incubator kept constantly at a temperature of 25°C. Following the same procedure, new stock cultures were always started as soon as a new generation of adult beetles appeared in the jars. The emerged beetles were not used for experimentation until the sixth generation elapsed; thus ensuring the use of experimental insects that were genetically and phenotypically alike.

To obtain newly-emerged beetles, i.e., egg-laying had not yet started, a jar in which a new generation had just appeared was taken, say at 8 a.m., and the weevils emerged therein removed. By 8.30 the same morning, all the weevils newly-produced in the jar, and which were half an hour or less old, were taken for experimental use and were considered newly-emerged. They could not have laid any eggs since in this particular insect mating was found to occur any time after emergence, and the deposition of the first egg proved experimentally to happen, at all the temperatures and humidities used, within at least half an hour from copulation.

In other instances, just-emerged unmated weevils were needed. These were obtained as follows : mated females were allowed to oviposit on unfested cowpeas in a jar for a day, after which time the females were removed. The seeds with the eggs laid on them were taken and on each seed only one egg was left, other eggs being removed with a needle. Each seed was then put in a 1 x 1/2 inch glass tube which was covered with muslin held in place by rubber band. All these tubes were put under the standard conditions of 25° C. and 75% R.H., and the seeds left therein until the adults were about to emerge (this was known by the appearance of a dark circular spot on the exterior of the seed) when the tubes were put under constant observation so that any weevil would be taken the minute it emerged. The enclosure of each emerged weevil in a separate tube ensured its virginity. The original eggs, being all laid on the same day, permitted many weevils to emerge at one time so that the collection of the necessary number of unmated weevils had not been a laborious task since it did not take more than a few hours.

To produce the desired relative humidities, stock solutions of sulphuric acid or potassium hydroxide in distilled water were prepared and were checked and readjusted from time to time.

For controlling the humidity, desiccators with well-fitting and slightly-greased lids were used. Into the bottom of each desiccator was introduced 120-150 cc. of the appropriate solution required to give the desired relative humidity. Care was taken that the necessary humidity solution be put in the desiccator 24 hours before its use in an experiment. The humidity solutions inside the desiccators were also replaced by fresh readjusted ones once every week, thus ensuring the exposure of the experimental insects to the same specific humidity all the time throughout an experiment.

Before use, the seeds were sterilized by being heated in an oven at 80-90°C. for 6 hours. Then, they were conditioned to each of the different humidities required for the experiments. Six weeks were needed for blackeyed cowpeas, chickpeas, or hyacinth beans to reach equilibrium with the different relative humidities; seven weeks for field peas and soybeans; and eight weeks for broad windsor beans and red Canadian Wonder beans.

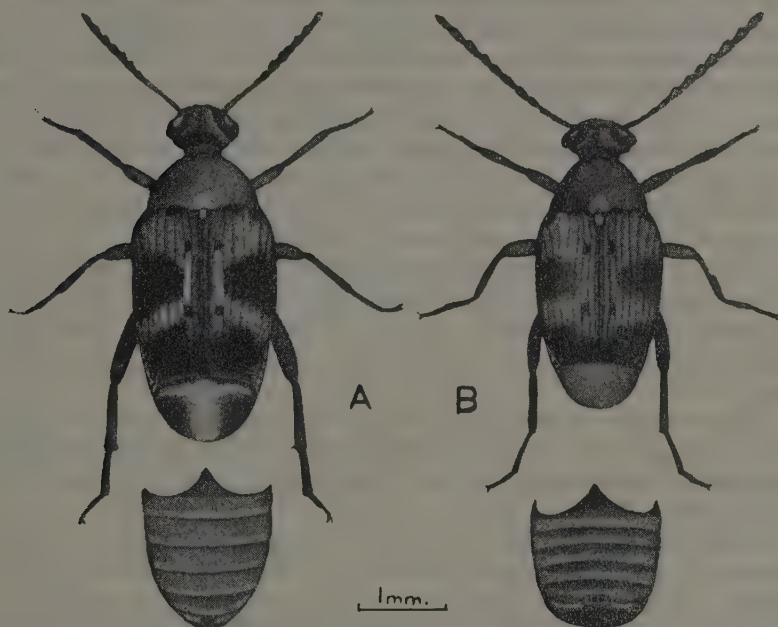


Fig. 1 : *Callosobruchus maculatus* (A, adult female, and its abdomen in ventral view; B, adult male, and its abdomen in ventral view).

For controlling the temperature, several electric water-jacketed incubators were used. In cases of low temperatures, the incubators were put in a cooled, air-conditioned room.

For individual experiments the weevils were sexed in the adult stage. This was easily accomplished by examining the pygidium, which in the female has on its dorsal side two large, dark patches separated from each other by a line of white pubescence; whereas in the male no such spots were observed, and the pygidium is dorsally covered with minute yellowish hairs. Another sex-distinguishing feature is that the pygidium of the male possesses a median ventral curvature into the hypopygidium readily visible under the binocular microscope, while in the female no such curvature is found. In addition, the female's abdomen appears oval-shaped ventrally, with its

distal extremity somewhat attenuated; whereas in the male the ventral side-lines of the abdomen are almost vertical so that the far end looks abruptly truncated. Also aiding in distinguishing the sexes is the fact that the female is darkly-coloured and always possessing the four elytral spots characteristic of the species, in contrast to the male which is pale-brownish in colour and almost always non-spotted or in some cases devoid only of the posterior elytral maculae. These sex-distinguishing features are shown in Figure 1.

In making the daily counting of eggs during an experiment, it was necessary to minimize the time of exposure of the experimental adults to the laboratory conditions which were different from those intended for the experiment. This was done by quickly transferring the beetles of each tube to a clean one containing a fresh supply of host seeds, and the new tubes put rapidly into the proper desiccator which was returned back to the desired temperature. This being accomplished, the old tubes were taken and the eggs laid on the contained seeds counted at leisure.

Care was exercised that the experiments concerning the durations of the developmental stages be started with eggs deposited on the first day of the females' lives since the well-known fact that eggs laid at a later period might be weaker and this giving longer and misleading periods of development.

In all the experiments dealing with the incubation periods of the eggs, eclosion was considered to happen when the black head of the hatching larva had appeared inside the egg and the chorion turning from the translucent state to opaque white.

During the course of the experiments it was observed that the adults before dying passed through a moribund period of short duration. Such moribund insects were not considered dead. Dead insects, however, were distinguished by the characteristic position of their legs, the latter being laid stretched alongside the body. On the contrary, the legs of moribund insects were flexed close to the body in a manner resembling that of feigning death, and when these legs were touched with the tip of a needle they were forced to move slightly.

After death, the original adults of each experiment were dissected to investigate the condition of their fat body and the amount of eggs remaining in the females' ovaries.

The results of each experiment were analysed statistically. The method used for testing the data was the analysis of variance. In a few cases, where the analyses involved two variables only, an ordinary "t" test of significance was used.

III. DAMAGE AND ANNUAL GENERATIONS IN EGYPT

There are only a limited number of references dealing with the damage

done to cowpeas by *Callosobruchus maculatus* F. In California, L a r s o n (1924) showed experimentally that the planting of weevily cowpeas reduced the yield through the following factors : (1) by injuring the embryos and causing a large percentage of the seeds failing to germinate, (2) by accelerating the decomposition of the seeds while they are germinating, (3) by holding the cotyledons together, thus preventing the development of the primary leaves, and (4) by removing and making unavailable much of the seed-food which aid the young plant in becoming well-established, thus making weak unproductive plants. Writing about the economic importance of this Bruchid in California, L a r s o n (1927) stated that : ".....In some sections farmers have discontinued growing cowpeas because of the heavy loss due to the ravages of this insect. Frequently, the entire crop, which at the time of storing shows no apparent weevil injury, in a short time is a total loss. With blackeyed cowpeas, and probably with other varieties, this loss is caused not only by the number and amount of the seeds actually devoured but by the mould and decay, which.....usually follows more promptly the attack of this weevil than of any others". Other experiments carried out in southern California by L a r s o n and F i s h e r (1924) showed that 69 pounds of blackeyed cowpeas originally infested with 25 pairs of this weevil were reduced, within a period of 7.5 months, to 26.25 pounds, with a loss of about 62% in weight. At Potchefstroom, Union of South Africa, O o s t h u i z e n (1940) reported that heavily infested seed lost up to 50% of its weight in 3 months. In terms of money, L a r s o n and F i s h e r (1938) quoted K i e f f e r (1927) stating that the bean growers in only three counties of California have suffered on their 1926 crop a loss of 1 to 1.25 million dollars due to the ravages of the two species *Bruchus obtectus* Say and *Callosobruchus maculatus* Fab.

Concerning the number of generations that the southern cowpea weevil develops during a year, very few references were noticed. L a r s o n and F i s h e r (1938) quoted W a d e (1919) and S a n b o r n (1919) stating that it had seven generations, with an eighth partly developed, in Oklahoma. The former writers also reported that in California they observed six generations to this insect in some years and seven generations in others, and that the generations were overlapping, the progeny produced by one generation varying so much in time that the earliest emerging individuals may produce another generation some of which would emerge before the more slowly-developing individuals of the first had come out. At Potchefstroom, Union of South Africa, O o s t h u i z e n (1940) stated that as many as six generations had been recorded from September to May, with the possible occurrence of a partial seventh generation during the winter months.

Indeed, an estimation of the damage done to cowpeas by *Callosobruchus maculatus* F., and the yearly number of generations it develops, have not been

worked out before in Egypt.

In a trial to measure the amount of damage done by *Callosobruchus maculatus* F. to stored cowpeas under the climatic conditions prevailing in Egypt, 990 grams of unfested blackeyed cowpeas were put in a big glass jar on the 12th. of April, 1952. After introducing 8 females and 15 males in the jar, the latter was covered with muslin secured by rubber bands and left in the open exposed to weather conditions. On the 17th. of July the same year, there were 4 generations of adult weevils emerged in the jar. By that time, the contents of the jar were nothing but a mouldy mass of infested seeds together with frass and adult insects, dead and alive. Then the frass and weevils were cleared off, and the remainder was weighed. It was found that the original 990 grams of cowpeas were reduced to 482 grams; the loss in weight amounting to 51.3%. This heavy loss in weight was due to the damage done by the progeny of only 8 mated females during a period not exceeding 3 months. However, the loss in weight due to the weevil infestation was actually much higher than the figure calculated, because many emerged weevils crawled back into the emergence holes and died there, and some larvae and pupae died or were still living within the cowpeas; their combined weights would materially reduce the remaining 482 grams, so that the actual percentage loss in weight must be highly over 51.3%.

The number of generations in Egypt was ascertained by allowing adult beetles to oviposit, on April 12, 1952, on sterilized cowpeas placed in a one-pound jar covered with muslin and exposed to room temperature and humidity. Each time a new generation of adult weevils appeared, few males and females were immediately taken out and allowed to oviposit on a fresh supply of unfested cowpeas placed in another clean jar. This was continued for a whole year during which records were made of the number of generations produced.

It was found that from April 12, 1952, to May 9, 1953, there had been eleven generations in the following order : April 12, 1952, adults were placed with cowpeas and allowed to oviposit; May 16, adults of the first generation emerging; June 8, adults of the second generation emerging; July 1, adults of the third generation emerging; July 24, adults of the fourth generation emerging; August 15, adults of the fifth generation emerging; September 5, adults of the sixth generation emerging; September 26, adults of the seventh generation emerging; October 22, adults of the eighth generation emerging; November 23, adults of the ninth generation emerging; February 25, 1953, adults of the tenth generation emerging; May 9, adults of the eleventh generation emerging.

The following were the average monthly records of temperatures and relative humidities that prevailed during the period of the experiment : April, 1952, 20.2°C., 55 % R.H.; May, 23.7°C., 49 % R.H.; June, 26.0°C.,

52 % R.H.; July, 27.6 °C., 54 % R.H.; August, 28.1 °C., 57 % R.H.; September, 27.7 °C., 62 % R.H.; October, 24.4 °C., 59 % R.H.; November, 19.3 °C., 65 % R.H.; December, 16.7 °C., 71 % R.H.; January, 1953, 12.7 °C., 59 % R.H.; February, 14.9 °C., 62 % R.H.; March, 14.5 °C., 55 % R.H.; April, 20.1 °C., 55 % R.H.; May, 23.9 °C., 52 % R.H.

IV. THE EFFECT OF CONSTANT TEMPERATURES AND HUMIDITIES DURING THE ADULT STAGE UPON THE LONGEVITY AND OVIPOSITION OF THE IMAGOS

Experiments

To study the influence of combined temperature and humidity acting during the adult stage of *Callosobruchus maculatus* F., upon the longevity and oviposition of the imagos, several series of experiments were conducted at five different constant temperatures and four different controlled relative humidities. The temperatures used were 18, 21, 25, 31, and 35°C., each of which was maintained with each of the following humidities : 55, 65, 75, and 90% R.H.

The adult insects used in these series of experiments were all newly-emerged and taken from cultures reared to maturity on blackeyed cowpeas at the constant conditions of 25°C. and 75% R.H. One male and one female were put in a 2×1 inches specimen tube containing five blackeyed cowpeas previously conditioned to the relative humidity intended to be used in the specific series of experiment. The tube was then covered with muslin secured in position by a rubber band. For every experimental series 25 of such tubes were made and placed in a desiccator at the required humidity, and the desiccator then put at the temperature wanted.

The 25 tubes of every experimental series were examined each morning until the death of the adults. Daily egg-counts were made for each individual mated female separately by the method described in the technique. Hence, the daily and the total number of eggs laid by every female were known. By recording the dates of emerging, of starting and stopping of egg-laying, and of death of the parent insects of each experimental series, it was possible to determine the longevity of the adults, the durations of the three oviposition periods, namely, the pre-oviposition, oviposition, and post-oviposition periods.

The results of these experiments are summarised in Tables I, II and III.

Discussion

(1) The effect of combined temperatures and humidities during the adult stage on the longevity of the imagos

(a) *The effect of temperature*

The general fact that the longevity of adult insects is increased with the decrease in the temperature to which they are exposed has been pointed out long ago by several authors. The following examples might appreciably be cited.

Loeb and Northrop (1916) and Alpatov and Pearl (1929) came to the same conclusion that the increase in the life span of the adult *Drosophila* was approximately proportional to the decrease in the temperature, and that there existed for the duration of life a temperature coefficient whose order of magnitude was the same as that required by Van't Hoff's rule for chemical reactions, namely, of about two for a decrease of 10°C., i.e., $Q_{10} = 2$. This same relationship was found to be true for the bean weevil, *Acanthoscelides obtectus* Say, independently by Menusan (1934) and by Zazou (1948).

TABLE I

Summary of the adult male and female longevitys (in days) as affected by different temperatures at different levels of humidities acting during the adult stage of Callosobruchus maculatus F.

(Rearing of experimental insects at 25°C. and 75 % R.H. — Means of days for 25 adults)

HUMIDITY TREATMENTS	TEMPERATURE TREATMENT MEANS										MEAN PER INSECT	
	18°C.		21°C.		25°C.		31°C.		35°C.			
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
55% R.H.	19.92	22.68	12.88	13.36	11.80	12.08	8.04	8.08	6.04	6.88	11.736	12.616
65% R.H.	20.68	23.16	13.88	14.32	13.48	13.96	8.28	8.36	6.16	7.04	12.496	13.368
75% R.H.	22.92	25.00	14.48	15.04	13.80	14.04	8.36	8.68	6.08	7.08	13.128	13.968
90% R.H.	23.20	25.28	15.56	16.04	14.96	15.16	9.08	10.20	6.28	7.24	13.816	14.784
MEAN PER INSECT	21.68	24.03	14.20	14.69	13.51	13.81	8.44	8.83	6.14	7.06	12.794	13.684

♂ ♀

L.S.D. (P=5%) between means of temperature = 0.62, 0.62, day.

L.S.D. (P=5%) between means of humidity = 0.55, 0.56, day.

In the present work on *Callosobruchus maculatus*, the analyses of variance of the data obtained on the longevity of the adults of either sex as affected by the different combinations of temperatures and humidities acting during the adult stage clearly showed that the effect due to temperature changes was very highly significant statistically.

The mean longevity per insect, as shown in Table I, decreased as the temperature during the adult stage was increased. For the male, increasing the temperature from 18 to 21°C decreased the longevity from 21.68 to 14.20 days. Further gradual increase in the temperature to 25, 31 and 35°C. resulted in a gradual decrease in the male longevity to 13.51, 8.44, and 6.14 days, respectively. Similarly with the female, the gradual increase in the temperature from 18 to 35°C caused a progressive decrease in the longevity from 24.03 to 7.06 days. Evidently, the differences between every two successive means of temperature treatments were all highly significant statistically since they were all well above the least significant difference calculated for the experiment. This was true for both sexes.

The present results are in general agreement with those arrived at in 1923 by Brauer (as cited by Larson and Fisher (1938)) who found that the average length of life of the adults of the southern cowpea weevil was 26, 10, 7, 6, and 1.5 days, respectively, at temperatures of 15, 27, 34, 37, and 44°C. However, Brauer apparently did not distinguish between the longevity of the two sexes.

Viewing the figures of the longevity per insect presented in Table I, it becomes obvious that there was a difference between the sexes in their mean duration of life as affected by the different temperature treatments. At all the temperatures used, the females lived longer than the males, although the difference between female and male longevities was much more marked at the lower temperature of 18°C. (it being 2.55 days) than at the higher temperatures (it being 0.49, 0.30, 0.39, and 0.92 days, respectively, at temperatures of 21, 25, 31, and 35°C.).

Plotting the mean durations of adult life against the corresponding temperatures acting during the imaginal stage, it becomes apparent that the data for both sexes almost give a straight linear distribution. We are, therefore, justified in concluding that, within the temperature limits here used, the duration of life is an exponential function of the temperature acting during the imaginal life.

Now, let us consider whether the decrease in longevity with the rise in temperature is of the same order of magnitude as that of chemical reactions. Examining the figures given in Table I for the longevity of the males at the different temperatures, we find that increasing the temperature from 21 to 31°C. resulted in a decrease in the longevity from 14.20 to 8.44 days, or with a coefficient of 1.7; while the rise in temperature from 25 to 35°C. decreased the length of life from 13.51 to 6.14 days, or with a coefficient of 2.2. Turning to the figures given in Table I for the longevity of the females, we find that the corresponding coefficients are $14.69/8.83 = 1.7$ and $13.81/7.06 = 1.96$. Hence, it can be seen that in both sexes the longevity of the adults is nearly doubled by every decrease of 10°C. in temperature, or, in other words, the

Van't Hoff's rule applying to the southern cowpea weevil.

Two alternative hypotheses have been advanced to explain this temperature effect upon the duration of life. The first, which is basically chemical in its nature, suggested that the duration of life is determined by the production of substances leading to old age and natural death, and that the temperature controls the rate of production of these hypothetical chemical substances. The second hypothesis, or the rate of living theory of life duration, which is essentially biological and based on experimental evidence and observed facts, is nearer to the truth. This theory maintains that the activity of an insect is, within limits, greatly modified by temperature, so that at low temperatures the insect becomes sluggish while at high temperatures it becomes exceedingly active and restless, and that the total duration of life varies inversely with the rate of energy expenditure in living (growth, muscular movement, etc.).

Regarding the southern cowpea weevil, *Callosobruchus maculatus*, the writer is inclined to interpret its proportionately decreased duration of imaginal life with the increase in temperature on the simple basis that it is more active at higher temperatures, or, in other words, has a higher rate of living and energy expenditure, and, correspondingly, the longevity is shortened, and vice versa. This interpretation is probably supported by the fact that at all the temperatures used in the experiment the adults of both sexes when dissected after their death were found to be almost entirely devoid of reserve fat body.

(b) *The effect of relative humidity*

The effect of atmospheric moisture upon the speed of insects' metabolism is seemingly extremely variable. It has been shown that whereas moist air retarded the development in some cases, it hastened it in others. Still in some other insects neither dry nor moist air seemed to materially affect the speed of metabolism.

Headlee (1917) found that, at a constant temperature of 80°F., the adult life of the moth *Sitotroga cerealella* was shortened by a decrease in atmospheric humidity. He, therefore, concluded that the speed of adult metabolism in the moth varied inversely with the humidity.

Menusan (1934) and Zazou (1948), working independently on the bean weevil, *Acanthoscelides obsoletus*, came to the same conclusion that the adults were not particularly sensitive to changes in humidity, but, however, the length of adult life slightly decreased as the relative humidity decreased.

In the experiments carried out on *Trichogramma evanescens*, Lund (1938) noticed that, at the standard condition of 25°C., the adult parasites were able to live their normal span of life at about 5 mm. saturation deficiency or lower, but at 10 mm. or higher the longevity was markedly reduced as a

result of the drying effect of the atmosphere.

In 1941, S c h o o f studied the effect, at constant $30 \pm 0.8^{\circ}\text{C}.$, of different relative humidities ranging from 0-3 to 91% on the duration of adult life of *Callosobruchus maculatus*. He found that the males lived slightly longer at above a relative humidity of 63% and the females slightly longer at and above one of 80% although the differences in duration were not significant statistically. However, he found also that at the humidities of 0-3 and 21% R.H. all weevils died within a very short time (males 1.5-2 days; females 1.5 days), while at the higher humidities a much greater period elapsed between the first and last deaths (males 3-7 days, females 2-4.5 days). From this he concluded that the humidities of 0-3 and 21% prevented the expression of any variations in vitality which the higher humidities allowed. He further added that neither sex showed the ability to outlive the other consistently.

In the present work on *Callosobruchus maculatus*, the analyses of variance of the data obtained on the longevity of the adults of both sexes, as affected by the different levels of humidity used during the imaginal life, clearly showed that the effect due to humidity changes was very highly significant statistically. The summarized results given in Table I show that at the respective humidities of 55, 65, 75, and 90% R.H., the mean longevity per male is 11.736, 12.496, 13.128, and 13.816 days, respectively; while the corresponding figures for the longevity per females are 12.616, 13.368, 13.968, and 14.784 days, respectively. This indicates that, regardless of the temperature, the mean duration of life of the adult progressively increases as the humidity during the adult stage increases since the differences between the successive mean longevities of humidity treatments are seen to be above the level of significance calculated for the experiment. This is true for both sexes, but there is no difference between the sexes as to sensibility to changes in humidity. Furthermore, it is seen from Table I that the increase in the adult longevity due to increase in the humidity is more pronounced at the lower temperatures ranging from 18 to $25^{\circ}\text{C}.$ than at the higher temperature of $31^{\circ}\text{C}.$, while at $35^{\circ}\text{C}.$ the humidity practically has no effect at all on the duration of adult life.

The general conclusion arrived at (that the imaginal longevity varies with the humidity to which the adults of the southern cowpea weevil are exposed) is expectable since we are dealing with an insect species that is totally dependent upon metabolic water, and, consequently, variations in atmospheric humidity should under such conditions prove effective. The increase in atmospheric humidity will prolong the adult life by preventing the rapid loss of the body fluid by evaporation, thus contributing to the maintenance of the internal water optimum.

(2) The effect of combined temperatures and humidities acting during the adult stage on oviposition

(a) The effect of temperature

That the temperature to which the adults are exposed is effective upon the oviposition of certain insects is well recognized. The following are some examples.

Bliss (1927) worked on the oviposition rate of five species and varieties of the grage leaf-hoppers, *Erythroneura*, under field conditions. Correlations were made firstly between laying rate and the mean temperature of the day the eggs were laid when the effect of the temperature of the preceding day was eliminated, and secondly between laying rate and temperature of the preceding day when the other factor was hypothetically made inoperative. From the data obtained he concluded that the temperature conditioned oviposition by its indirect effect upon the rate of egg-formation in the ovary more than by its direct action as an external factor upon egg-deposition.

Experimenting on the bean weevil, *Acanthoscelides obtectus*, Menušan (1935) found that, within the constant temperature range of 8.7 to 40.2°C., at 90% R.H., the temperature had a marked effect on both the rate and total amount of oviposition. The lower the temperature the longer the oviposition period was. The number of eggs deposited per female increased as the temperature was decreased from 40.2 to 27.1°C., while from 27.1 to 13.9°C. the number of eggs decreased as the temperature, but at a temperature of 8.7°C. the females died without ovipositing. He concluded that the optimum temperature for oviposition of the bean weevil was 27°C. at a relative humidity of 90%. More or less similar conclusions were arrived at by Zazou (1948) for the same insect. This latter author found that, at all the humidities used (ranging from 30 to 100% R.H.), the total number of eggs deposited increased as the temperature was increased from 15 to 25°C., but that at 30°C. a reduction in the number of eggs laid was noticed. In concluding, he considered the optimum temperature to be 25°C. at high humidities (75 to 100 % R.H.).

Oosthuizen and Laubscher (1940) showed that the temperature to which the adults of *Bruchus analis* Fab., were exposed had a marked influence on the total egg-production per female. The egg-production at the constant temperature of 77°F. was almost double that at room temperature ($\pm 54^\circ\text{F.}$), but dropped considerably at constant 86°F.; the mean per female being 60.8, 32.6, and 50.7 eggs, respectively,

Regarding the insect under present study, namely *Callosobruchus maculatus*, a survey of the literature showed that practically no systematic studies have been made on the effect of constant temperatures upon the number of eggs

deposited and the three periods of oviposition. The only references that might be considered to bear some relation to this subject were those of Brauer (1925) and Larson and Fisher (1938). Brauer stated that the average number of eggs laid by one female was about 70, and that at a temperature of 33°C. she laid this number of eggs in from 3 to 5 days, but at a lower temperature (unstated) the same number of eggs were deposited over a longer interval of time. Evidently, this statement of Brauer might mean that the temperature did not affect the number of eggs deposited by a female but that it only affected the duration of the oviposition period. On the other hand, that the temperature is an important factor to both the oviposition period and the number of eggs laid by the females of the southern cowpea weevil is evident from the work of Larson and Fisher (1938) in California. From a record of the typical pre-oviposition periods throughout a year under natural conditions, they concluded that the pre-oviposition period was longer in cool or cold weather. In another part of the same paper they concluded also that more eggs per day and per weevil were laid during warm weather than during cold weather, and that at the higher temperatures of the summer the maximum oviposition period lasted only 13 days, whereas at the lower temperatures of the winter egg-deposition extended for as long as 36 days.

TABLE II

Summary of the total number of eggs laid by the female as affected by different temperatures at different levels of humidities acting during the adult stage of *Callosobruchus maculatus* F.

(Rearing of experimental insects at 25°C. and 75% R.H. — Means of eggs for 25 adults).

HUMIDITY TREATMENT	TEMPERATURE TREATMENT MEANS					TOTAL	MEAN PER INSECT
	18°C.	21°C.	25°C.	31°C.	35°C.		
55% R.H.	48.52	69.52	71.32	58.20	50.36	297.92	59.584
65% R.H.	49.80	72.08	78.48	63.76	58.96	323.08	64.616
75% R.H.	50.44	75.36	81.00	76.72	51.92	335.44	67.088
90% R.H.	51.32	77.52	89.68	77.92	56.72	353.16	70.632
TOTAL	200.08	294.48	320.48	276.60	217.96	1309.60	
MEAN PER INSECT	50.02	73.62	80.12	54.49	54.49		63.480

L.S.D. (P=5%) between means of temperature = 3.58 eggs.

L.S.D. (P=5%) between means of humidity = 3.20 eggs.

In the present experiment on *Callosobruchus maculatus*, it was observed that, at all the combinations of temperatures and humidities used, the first

egg was deposited within 30 or more minutes from copulation. This is in general agreement with the findings of Larson and Fisher (1938) and of Brauer (1925). The former collaborators mentioned that in the warm summer weather of California eggs may be laid within a few minutes or hours from mating, and that they had observed females laying their first egg 31 minutes, 46 minutes, or 2 hours after mating. The latter author reported that the female began oviposition few hours after copulation.

The data obtained on the effects of the different combinations of temperatures and humidities on the average daily number of eggs deposited per female showed that at the moderate temperatures (21 to 31° C.) there was a tendency towards heavy steady oviposition during the first few laying days and a gradual decrease in the number of daily eggs as the female became older. At the higher temperature of 35°C. most of the eggs were deposited on the second and third day after emergence and then followed a sudden heavy drop in the number of eggs laid during the few laying days remaining before the female died. But, at the lower temperature of 18°C., a very marked difference occurred; the female tending to oviposit at a greatly reduced rate per day stretched over a significantly longer egg-laying period, and there was also an irregular intermittence of high and low rate of daily oviposition during the successive egg-laying days.

The low egg-production during the first day after emergence at either high (35°C.) or low (18°C.) temperatures might possibly be accounted for by the delay in mating, the latter occurring late in the first day so that a fewer number of eggs is laid during this first day.

There was also a negative relation between the length of life of the female and the average egg-production per day. The long-living (or "cold") weevils had a low average egg-production per day; while those which had a short life ("warm" weevils) had a high average egg-production per day. This conclusion appears to support the "rate of living" theory of life duration; the greater the expenditure of energy in egg-production during the reproduction period, as indicated by daily rate, the shorter the duration of life, and vice-versa.

The analysis of variance of the data obtained on the total number of eggs laid per female as affected by the different combinations of temperatures and humidities showed that the effect due to temperature changes was very highly significant statistically. The summarized results given in Table II show that, regardless of the humidity to which the adults were subjected, the highest number of eggs (80.12) were laid at the temperature of 25°C., which, therefore, might be designated as the optimum temperature for oviposition. Any change in temperature above or below this optimum caused a highly significant reduction in the number of eggs laid by the female; the average egg-production per female being 50.02, 73.62, 69.15, and 54.49 eggs, res-

pectively, at temperatures of 18, 21, 31, and 35°C., and the least significant difference calculated for the temperature effect being 3.6 eggs.

This clear change in the average total egg-production per female according to the temperature to which the adults are exposed is in partial accordance with the previously mentioned findings of Larson and Fisher in which they concluded that, under natural conditions, more eggs were laid during warm weather than during cold weather. On the contrary, this is in complete disagreement with what Brauer's statement seemingly indicate (that the same number of eggs are laid at 33°C. as at a lower temperature, with a difference in the length of the oviposition period only).

The deposition of the first egg, at all temperatures and humidities, during the first few minutes or hours after emergence and mating seem to indicate that the female emerges with its ovaries fully-developed and that no time is required for the eggs to ripen. This, together with the fact that all the experimental parent females being reared under the same standard conditions of 25°C. and 75% R.H., render it necessary to exclude the possibility that the temperature acting during the adult stage affects the number of eggs deposited by its indirect influence upon egg-formation in the ovaries. It is thus apparent that the temperature to which the adults are subjected influences the total number of eggs laid per female by its direct effect upon the mechanism of egg-deposition so that any decrease or increase in temperature from the optimum causes a decrease in the number of eggs deposited. This is substantiated by the fact that when the parent females were dissected after death, those that were living at the optimum temperature of 25°C. were found to have laid their full capacity of eggs; while the ovaries of those being kept at a higher or lower temperature were found to contain some undeposited eggs. The quantity of undeposited eggs remaining in the ovaries, however, was found to be proportionate to the gradual increase or decrease of temperature from the optimum. In other words, more eggs remained within the female at 35 than at 31°C., and at 18 than at 21°C.

It was observed also that the highest average total egg-production per mated female was 89.68 which occurred when the female was kept as adult at 25°C. and 90% R.H. This average is considerably above the averages 73, 70 and 82, as given by Paddock and Reinhard (1919) (as cited by Larson and Fisher (1938)), Brauer (1925), Larson and Simmons (1923), respectively, and is highly below the average of 104.48 given by Larson and Fisher (1938). These differences in egg-production go to substantiate the finding of Breitenbecher (1926) who stated that certain strains produce more progeny than others. Another observation was that the highest maximum total number of eggs laid by an individual female was 123 eggs (that of one weevil kept at 25°C. and 90%

TABLE III

Summary of the 3 oviposition periods (in days) as affected by different temperatures at different levels of humidities acting during the adult stage of Callosobruchus maculatus F.

(Rearing of experimental insects at 25°C. and 75% R.H. — Means of days for 25 adults)

HUMIDITY TREATMENTS	TEMPERATURE TREATMENT MEANS												MEAN PER INSECT					
	18°C.			21°C.			25°C.			31°C.				35°C.				
	(1) (2)		(3)	(1) (2)		(3)	(1) (2)		(3)	(1) (2)		(3)		(1) (2)		(3)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)		(1)	(2)	(3)		
55% R.H.	1.60	17.00	4.08	0.08	10.24	3.04	0	8.16	3.92	0	4.80	3.28	0.68	3.80	2.40	0.472	8.800	3.344
65% R.H.	1.28	17.80	4.08	0.04	11.12	3.16	0	10.72	3.24	0	5.12	3.24	0.36	4.64	2.04	0.336	9.880	3.152
75% R.H.	0.96	18.84	5.20	0.04	12.12	2.88	0	10.20	3.84	0	6.12	2.56	0.40	3.72	2.96	0.280	10.200	3.488
90% R.H.	0.44	17.80	7.04	0.04	12.36	3.64	0	11.80	3.36	0	7.24	2.96	0.08	4.92	2.24	0.112	10.824	3.848
MEAN PER INSECT	1.07	17.86	5.10	.05	11.46	3.18	0	10.22	3.59	0	5.82	3.01	0.38	4.27	2.41	0.300	9.926	3.458

L.S.D. (P=5%) between means of temperature = 0.16 (1) (2) (3)

L.S.D. (P=5%) between means of humidity = insignificant 0.54 0.51

N.B. : (1) = Pre-oviposition period; (2) = oviposition period; (3) = post-oviposition period.

R.H.), as compared to the maxima 115 and 196, as given by L a r s o n and S i m m o n s (1923) and L a r s o n and F i s h e r (1938), respectively.

As to the pre-oviposition period, the analysis of variance of the data obtained on its duration at the different combinations of temperatures and humidities showed that the effect due to temperature changes was very highly significant statistically. It is evident from Table III that, as far as the accuracy of one day's observations permits, the pre-oviposition period was almost nill at 21, 25, and 31°C., respectively; while at the high temperature of 35°C. or the low temperature of 18°C., the pre-oviposition period was significantly increased, it averaging 0.38 day in the first case and 1.07 days in the second case. Considering that for the temperature effect the least significant difference calculated was 0.16 day, it is concluded that the pre-oviposition period is pronouncedly affected by the rise of the adult temperature to 35 or its lowering to 18°C.

That the pre-oviposition period of the female of *Callosobruchus maculatus* is affected by the temperature is also understood from statements given by L a r s o n and F i s h e r (1938) who reported that the recording of the typical pre-oviposition period in California throughout a year showed it to be longer in cool or cold weather than at favourable summer temperatures where oviposition usually begins during the first day after emergence.

A reasonable interpretation of the increase in the pre-oviposition period at 35 and 18°C. may be that in these temperatures mating is delayed due to the restlessness or the sluggishness, as the case may be, of the adult weevils with the result that egg-laying is delayed too, and thus an increase in the pre-oviposition period follows.

The analysis of variance of the data obtained on the oviposition period as affected by the different combinations of temperatures and humidities showed that the effect due to temperature changes was very highly significant statistically. The summary of the results given in Table III shows that the temperature to which the females were subjected had a great influence upon the duration of the period on which the eggs were laid; this period being markedly decreased as the temperature was gradually decreased from 18 to 35°C. It is seen that at temperatures of 18, 21, 25, 31, and 35°C., respectively, the average oviposition period was 17.86, 11.46, 10.22, 5.82, and 4.27 days; the differences between these successive periods are evidently above the 0.54 day level which is the least significant difference calculated for the temperature effect in this particular experiment.

These results partly coincide with the findings of others authors on the same insect. Thus, B r a u e r (1925) mentioned that the oviposition period at 33°C. was 3 to 5 days, while at a lower temperature it became longer. Records made in California in summer and in winter by L a r s o n and F i s h e r (1938) indicated that at the higher temperatures the maximum

oviposition period lasted only 13 days, whereas at the lower temperatures egg-deposition extended for as long as 36 days.

The higher the temperature the shorter the oviposition period is explainable on the previous finding that the higher the temperature the higher the daily rate of oviposition, hence an increased energy expenditure in egg-laying and a shorter period of egg-deposition.

The analysis of variance of the data obtained on the post-oviposition period as affected by the different combinations of temperatures and humidities showed that the effect due to temperature changes was very highly significant statistically. The summarized results shown in Table III indicate that the average post-oviposition period is also proportionately decreased by the increase in the temperature from 18 to 35°C., with only two irregularities visible. Firstly, that the post-oviposition period at 25°C. is seen to be a little higher than it should be, but this is to be expected under the present results since under 25°C. and 75% R.H. there existed a post-oviposition period of 12 days which seems odd and might have altered the results. Secondly, that the increase in temperature from 21 to 31°C., although causing a decrease in the post-oviposition period, yet the difference is highly below the least significant level calculated for the temperature effect. Therefore, a sound conclusion to be drawn from the present results is that at 21, 25, and 31°C. the post-oviposition period is almost the same, but if the temperature is increased to 35°C. this period is considerably reduced, while the decrease of the temperature to 18°C. causes a pronounced increase in the post-oviposition period.

(b) *The effect of humidity.*

The effect of humidity during the adult stage on oviposition was studied by Menusan (1935) in the bean weevil, *Bruchus obtectus* Say. From experiments carried out at 25.2°C. and at different relative humidities ranging from 1 to 98%, he concluded that the time required for oviposition did not appear to be affected though the rate at which the eggs were deposited varied with the different humidities. He found that the highest rate and thereby the greatest number of eggs were deposited at 90% R.H. Increasing the relative humidity to 98% caused a reduction in the number of eggs. Lowering the humidity to 75 or 50% R.H. also decreased the number of eggs laid per female; whereas females at humidities varying from 1 to 25% R.H. deposited about the same number of eggs, but there was a marked increase in the number if the relative humidity was increased to 50%. Working on the same insect, at temperatures ranging from 15 to 30°C. and relative humidities ranging from 30 to 100%, Zazou (1948) found that, at the low temperature, increasing the relative humidity over 55% caused little or no increase in the number of eggs; whereas at the other temperatures the number of eggs laid

by a single female increased as the relative humidity was increased up to 90%. In addition, he found that, owing to the irregularity of the results, a clear relation between the relative humidity and the pre- and post-oviposition periods could not be detected, but that the oviposition period showed a tendency to increase as the relative humidity was increased. The 90% R.H., which was found to be the optimum humidity for oviposition, proved to be the humidity at which the post-oviposition period was longest.

Regarding the oviposition of the southern cowpea weevil, *Callosobruchus maculatus*, as affected by the humidity at which the adults live, the only work that has been met with in the literature was that of Schoof (1941). He investigated the rate of egg-production at $30 \pm 0.8^\circ\text{C}$. and at relative humidities of 0.3, 21, 44, 63, 80, and 91%, respectively, and found that the average number of eggs laid per female at those respective humidities was 39.7, 35.7, 48.3, 49.5, 57.1, and 54.1. Therefore, he concluded that the egg-production increased with the increase in relative humidity up to 80%. However, no mention has been made to the three oviposition periods or the daily egg-production.

In the present work on the southern cowpea weevil, the average daily egg-production as affected by the different combinations of temperatures and humidities indicated that, at all temperatures, there was a tendency towards an increase in the number of eggs laid daily per female as the relative humidity was gradually increased from 55% to 90%.

The analysis of variance of the data obtained on the total number of eggs laid by each female at the different combinations of temperatures and humidities clearly indicated that the response to humidity changes was significant statistically. It is evident from the summarized results given in Table II that the average total number of eggs deposited per female was increased as the humidity was increased; this number being 59.58, 64.62, 67.09, and 70.63, respectively, at relative humidities of 55, 65, 75, and 90%. Evidently, this is in general accordance with the previously mentioned finding of Schoof except in that the number of eggs in the present investigations is further increased with 90% R.H.

This humidity effect on the productivity is expected since, as we are dealing with a species that is totally dependent upon metabolic water, the prevention of high water loss should be reflected in the retention of the female until most of her eggs are laid.

As to the pre-oviposition period, it was clearly seen from the analysis of variance of the data obtained that the effect due to humidity changes was insignificant statistically. In other words, the relative humidity to which the adults were subjected had no influence at all on the pre-oviposition period of the females (Table III).

The analysis of variance of the data obtained on the oviposition period

showed that the effect due to humidity changes was highly significant statistically. Considering the summarized results shown in Table III relating to the effect of humidities on this period, we find that it increases according to the increase in relative humidity.

Regarding the post-oviposition period as affected by the humidities at which the adults lived, the statistical analysis of the data obtained indicated that the humidity had no effect at all on the duration of that period, the effect being insignificant statistically (Table III).

In conclusion, although the relative humidity under which the females of the southern cowpea weevil lived did not affect the pre- and post-oviposition periods, yet it influenced the daily egg-deposition, the total number of eggs deposited, and the oviposition period; any increase in the relative humidity causing a corresponding increase in any of these mentioned variables.

V. THE EFFECT OF CONSTANT TEMPERATURES AND HUMIDITIES ACTING DURING THE IMMATURE STAGES UPON THE LONGEVITY AND OVIPOSITION OF THE RESULTANT ADULTS

The fact that the adults of the southern cowpea weevil, *Callosobruchus maculatus* F., do not take solid food during their life and that they, under storage conditions, do not have the opportunity of gaining access to fluids of any kind, made their activities depend largely upon the energy accumulated during the developmental stages. Such being the case, it would be of considerable practical importance to find out how such important factors as temperature and humidity, while acting during the immature stages, would affect the longevity and oviposition of the resulting adults.

Experiments

To study this problem several series of experiments were conducted at three different constant temperatures and three different controlled relative humidities. The experimental insects were all reared to maturity on blackeyed cowpeas. The temperatures used during rearing were 21, 25, and 31°C., respectively, each of which was combined with each of the following humidities : 55, 65, and 75% R.H. From each of these rearing conditions, 25 newly-emerged adults (less than half an hour old) of either sex were taken. Each male-female couple was confined in a 2×1 inches specimen tube containing five blackeyed cowpeas previously conditioned at 75% R.H., and the tube was then covered with muslin secured by rubber band. The 25 tubes of each experimental series were placed in a desiccator at constant

75% R.H. All the desiccators of the different series of the experiment were maintained at the constant temperature of 25°C. Daily egg-counts for every female of each series were made and a renewal of the oviposition site was done every day until the parent insects died. Hence, the daily and, consequently, the total number of eggs laid per female were known. By recording the dates of emerging of the parent adults, of starting and stopping of egg-laying, and of death, it was possible to determine the longevity of the original imagos and the durations of the three oviposition periods.

A summary of the results for these experiments is presented in Tables IV, V, and VI.

Discussion

(1) The effect of combined temperatures and humidities during the immature stages upon the adult longevity

(a) The effect of temperature

Among the few attempts carried out to investigate the effect of temperature during the developmental stages of insects upon the duration of life of the resulting adults is that of Alpatov and Pearl (1929) on *Drosophila melanogaster*. They found that at a higher temperature (28°C.) during embryonic, larval and pupal development the duration of the subsequent life was shorter than when the developmental temperature was at 18°C.

Conversely, Lund (1938), working on *Trichogramma evanescens*, noticed that the longevity of both males and females was reduced as the temperature at which the immature stages were kept was lowered.

As to the bean weevil, *Acanthoscelides obsoletus*, Zazzo (1948) came to the conclusion that the adults which were reared to maturity at 30 or at 21°C. lived longer than those reared at 25°C., when all were kept during imaginal life at the standard conditions of 25°C. and 75% R.H.

It has been found by Raichoudhury and Jacobs (1937) that the longevity of the females of *Ephestia kuhniella* was determined solely by the temperature at which they were kept after emergence, and not by the temperature at which they were reared to maturity.

For the insect under the present study, no such work has been formerly made. In the present work, the analysis of variance of the data obtained on the effects of three different temperatures at three different humidities acting during the immature stages of *Callosobruchus maculatus* upon the longevity of the subsequent adults showed that in both sexes the effect due to temperature changes was very highly significant statistically. The sum-

marized results shown in Table IV indicate that when the rearing temperature is increased from 25 to 31°C. the mean longevity of the subsequent male is reduced from 12.40 to 9.92 days, with a difference of 2.48 days which is highly significant statistically. Also, when the temperature during the developmental stages is reduced from 25 to 21°C. it is seen that although the longevity of the male increased from 12.40 to 12.867 days, yet the difference of 0.467 day proved to be insignificant statistically as it is below the least level of significance calculated for the experiment. For the mean longevity per female we find that, as is the case with the male, the decrease of 3.013 days in longevity due to the increase in rearing temperature from 25 to 31°C. is highly significant statistically; but the reduction of the developmental temperature from 25 to 21°C. resulted in a practically negligible decrease of 0.106 day in longevity.

TABLE IV.

Summary of the adult male and female longevitys (in days) as affected by different temperatures at different levels of humidities acting during the immature stages of Callosobruchus maculatus F.

(Imagos kept during adult life at 25°C. and 75% R.H. — Means of days for 25 adults).

HUMIDITY TREATMENTS	TEMPERATURE TREATMENT MEANS						MEAN PER INSECT	
	21°C.		25°C.		31°C.			
	♂	♀	♂	♀	♂	♀	♂	♀
55% R.H.	12.76	12.96	12.36	13.24	9.16	9.88	11.427	12.027
65% R.H.	12.88	13.28	12.56	13.60	10.24	10.44	11.893	12.440
75% R.H.	12.96	13.44	12.28	13.16	10.36	10.64	11.867	12.413
MEAN PER INSECT	12.867	13.227	12.40	13.333	9.92	10.32	11.729	12.293

L.S.D. (P = 5%) between means of temperature = 0.64 0.65

Differences between means of humidity are insignificant statistically.

The safest conclusion to be drawn from these results is that an increase in the temperature acting during the immature stages of the southern cowpea weevil from 21 or 25 to 31°C. causes a decrease in the longevity of either sex of the resulting adults. Furthermore, it is apparent that the reduction in adult duration of life as a result of high temperature during development is greater in the females than in the males.

This indicates that, as far as the duration of imaginal life is concerned, the effect of temperature changes is of the same nature when acting during the immature stages as when influencing the adult stage. Therefore, the present conclusion could also be interpreted on the "rate of living" theory of life duration, because in both cases the effect of increased temperature is to speed

up the rate of the biological processes involved. In the 31°C. weevils there is a short developmental period and a consequent rapid rate of energy expenditure during growth and during imaginal life. This, according to the theory, leads to the expectation of a short duration of imaginal life, which is in fact observed. On the other hand, in the 21 and 25°C. weevils we have a relatively slower rate of energy expenditure in growth and during imaginal life, and we should therefore expect a lengthened duration of adult life, which we actually observe. This interpretation may probably be supported by the simple observation that, at the same imaginal temperature of 25°C., the adults of *Callosobruchus maculatus* which were reared to maturity at 31°C. were much more active than those emerging from a temperature of 25 or 21°C.

(b) *The effect of humidity*

The work done on the effect of humidity acting during the immature stages of insects upon the longevity of the subsequent adults is seemingly equally scarce. Lund (1938) found that the humidity in which the parasites *Trichogramma evanescens* were reared to maturity had no effect upon the longevity of the resulting adults.

For *Acanthoscelides obsoletus*, Z a a z o u (1948) concluded that the humidity in which the weevils were reared to maturity had a slight effect upon the longevity of the resultant adults, the effect being an increase in longevity as the relative humidity was increased.

In the present work on *Callosobruchus maculatus*, the analysis of variance of the data obtained showed that the effect of changes in humidity during development was statistically insignificant to the longevity of the subsequent males or females (Table IV). This indicates that whereas the humidity to which the adults were exposed materially affected the longevity of these adults, the humidity to which the eggs, larvae and pupae were subjected had no effect at all on the longevity of the subsequent adults.

**(2) The effect of combined temperatures and humidities
during the immature stages
upon the oviposition of the resultant females.**

(a) *The effect of temperature*

The literature dealing with the effect on productivity of temperatures under which the adults were reared to maturity is seemingly scarce as compared to that dealing with the effect of temperature under which the adults live. In other words, few attempts have been made to distinguish between the effects of temperature upon the development of the sexual functions or products and upon the process of egg-laying itself. Thus, Bliss

(1927) correlated egg-production in five different species and varieties of *Erythroneura* grape-leafhoppers with the temperature the day previous to oviposition and concluded that the temperature was found to condition oviposition more by its indirect effect upon egg-development than by its direct action on egg-deposition

Lund (1938) cited Eidman (1929) stating that lepidopterous pupae kept at a low temperature (unstated) produced adults which laid fewer eggs. Also, Uvarov (1931) quoted Pospelov (1919) finding that high temperatures did not affect the development of the ovaries in most species of Lepidoptera.

Alpatov (1932), working on *Drosophila melanogaster*, found that the adults reared to maturity at 30°C. produced fewer eggs than did others reared at 19°C., when all were kept as adults at 25°C. The experiments of Lund (1938) indicated that the opposite effect was produced on *Trichogramma evanescens*, since the rearing of this parasite at either higher or lower temperature than 25°C. reduced the subsequent productivity at the standard conditions of 25°C. and 5mm. saturation deficiency.

TABLE V

Summary of the total number of eggs laid by the female as affected by different temperatures at different levels of humidities acting during the immature stages of *Callosobruchus maculatus* F.

(Imagos kept during adult life at 25°C. and 75% R.H. — Means of eggs for 25 adults)

HUMIDITY TREATMENTS	TEMPERATURE TREATMENT MEANS			MEAN PER INSECT
	21°C.	25°C.	31°C.	
55% R.H.	87.28	79.68	53.76	73.573
65% R.H.	82.32	76.28	59.16	72.587
75% R.H.	83.28	79.00	58.72	74.000
MEAN PER INSECT	84.293	78.32	57.547	73.387

L.S.D. (P=5%) between means of temperature = 3.54 eggs.

Difference between means of humidity are insignificant statistically.

Regarding the bean weevil, *Acanthoscelides obsoletus* Say, Zazaou (1948) found that the total output of eggs per female increased as the rearing temperature was lowered.

As to *Callosobruchus maculatus* F., in fact nothing has been done before on the influence of temperature during the immature stages upon the oviposition of the subsequent adults.

In the present work, the results obtained on the effect of three different rearing temperatures, at three different relative humidities, on the average daily egg-production per female showed that, at all the developmental

temperatures used, there has been a tendency towards heavy rate of egg-production per female during the first few days and then followed a gradual decrease in the rate during the rest of the oviposition days. However, the number of eggs deposited during the first day was found to be greater in a rearing temperature of 25 than at either 21 or 31°C. But during the rest of oviposition days the rate of egg-laying per day decreased as the rearing temperature was increased. It was noticeable also that the period during which the eggs were laid was longest at the developmental temperature of 21°C., and that it decreased with the rise in the rearing temperature.

The analysis of variance of the data obtained on the total number of eggs deposited by the females, as affected by the different combinations of temperatures and humidities during the immature stages, showed that the effect due to temperature changes was very highly significant statistically. It is quite evident from the summarized results of Table V that the temperature at which the adults were reared to maturity has a great influence on the total number of eggs deposited per female. At the rearing temperature of 21°C. the female laid an average of 84.29 eggs, while at 25°C. the number of eggs came down to 78.32. A further increase in temperature to 31°C. again caused a decrease in the egg-production to 57.55 per female. The differences between the total number of eggs laid per female at these successive rearing temperatures are seen to be highly above the least significant difference of 3.54 eggs calculated for the temperature effect at this particular experiment. It is, therefore, concluded that the total number of eggs deposited is very markedly increased as the temperature at which the females were reared to maturity is lowered.

It is evident, therefore, that the egg-production of *Callosobruchus maculatus* is pronouncedly affected by the temperature acting during the immature stages as well as by the temperature at which the adults live. In other words, the oviposition is quantitatively conditioned by temperature both by its indirect effect upon egg-formation and by its direct effect upon the mechanism of egg-laying.

This increase in the number of eggs laid with the decrease in the temperature acting during the immature stages may be interpreted in such a way that the long developmental periods at a low temperature give to the genital system more chances to grow into a powerful organ than do the short developmental periods at a high temperature. The females reared to maturity at high temperatures may be supposed to have accumulated lesser "egg-producing substances" (fat-body) during their shorter larval and pupal life, and thus emerge with less productive gonads; and vice-versa.

The analysis of variance of the data obtained on the pre-oviposition period, as affected by the rearing temperatures and humidities, showed that the effect due to temperature changes was insignificant statistically; or, the

temperature at which the female was reared had no effect at all on its pre-oviposition period, the latter being in almost all cases less than one day as shown in Table VI.

The analysis of variance of the oviposition periods showed that the effect of different rearing temperatures upon the period was statistically highly significant. The summarized results shown in Table VI indicate that the oviposition period was longest (10.01 days) at the rearing temperature of 21°C. When the temperature was increased from 21 to 25°C, the oviposition period fell down to 9 days, and a further increase to 31°C. still caused the period to decrease to 7.61 days. As the least significant difference calculated for the temperature effect at this experiment was 0.5 day, and the differences between the periods were all above this level of significance, it is safe to say that the oviposition period decreases considerably as the rearing temperature is increased. Rearing the insect at low temperature may have caused an increase in the energy stored up during the relatively longer immature stages, which would lead to the emergence of a more powerful female that lays her eggs during a longer oviposition period.

TABLE VI

Summary of the 3 oviposition periods (in days) as affected by different temperatures at different levels of humidities acting during the immature stages of Callosobruchus maculatus F.

(Imagos kept during adult life at 25°C. and 75% R.H. — Means of days for 25 adults).

HUMIDITY TREATMENT	TEMPERATURE TREATMENT MEANS									MEAN INSECT PER		
	21°C.			25°C.			31°C.					
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
55% R.H.	0	9.96	3.00	0	9.00	4.24	0	7.36	2.52	0	8.773	3.253
65% R.H.	0	10.04	3.24	0	9.16	4.44	0.04	7.72	2.68	0.013	8.973	3.453
75% R.H.	0	10.04	3.40	0.04	8.84	4.28	0	7.76	2.88	0.013	8.880	3.520
MEAN PER INSECT	0	10.013	3.213	0.013	9.00	4.32	0.013	7.61	2.693	0.009	8.876	3.409
							(1)	(2)	(3)			
L.S.D.(P=5%) between means of temperature = insignificant, 0.50, 0.51										Difference between means of humidity are insignificant statistically.		
N.B. : (1) = Pre-oviposition period; (2) = oviposition period; (3) = post-oviposition period.												

The statistical analysis of the data obtained on the post-oviposition periods showed that the rearing temperature had a highly significant effect upon this period. It is apparent from the summarized results given in Table VI that the insects reared at 25°C. had the longest post-oviposition period; any increase or decrease from this temperature caused a reduction in the period.

(b) *The effect of humidity*

References dealing with the effects of humidity acting on the developmental stages upon the productivity of the subsequent adults are extremely rare, and indeed no work has been done on *Callosobruchus maculatus*.

For *Trichogramma evanescens*, Lund (1938) found out that the humidity in which the parasites were reared to maturity affected the productivity of the resulting adults ; the maximum egg-production being obtained at a humidity of 5mm. saturation deficiency, but both higher (saturation) and lower (15 mm. sat. def.) humidities reduced the productivity. He stated that "the effects of adverse moisture conditions are more pronounced when they act during the relatively long developmental period than when they influence directly the function of oviposition during the short adult life, only the first part of which is of much significance in the total productivity".

Working on the bean weevil, *Acanthoscelides obsoletus* Say, Zazaou (1948) concluded that the relative humidity acting upon the developmental stages or upon the adult itself had the same general influence on egg-production; the total output of eggs per female increasing as the relative humidity was increased.

In the present work, the data obtained on the southern cowpea weevil, *Callosobruchus maculatus*, showed that the humidity in which the adults were reared to maturity had no visible effect on the daily egg-production per female.

The effects of rearing humidities on the total egg-production per female proved to be insignificant statistically. It can be concluded from Table V that the humidity acting upon the immature stages has no influence on the total egg-output of the resulting females. Evidently, this is the contrary to its effect when acting on the adult stage where it was found that the total egg deposited per female increased with the increase in humidity.

It is then obvious that the humidity conditions oviposition of the southern cowpea weevil only by its direct effect on the process of egg-laying itself and not by its indirect action upon egg-development.

It was also evident that the humidities at which the females were raised to maturity had no effect upon the pre-oviposition, oviposition, and post-oviposition periods of the subsequent females, since the analysis of variance of the results obtained proved that the differences between the different treatments were insignificant statistically (Table VI).

To sum up, it is noticeable that the humidity influencing the immature stages of the southern cowpea weevil does not affect the resulting females in neither their daily and total egg-production nor their oviposition periods.

VI. THE EFFECT OF FOOD DURING THE LARVAL STAGES UPON THE LONGEVITY AND OVIPOSITION OF THE RESULTANT ADULTS

It has been stated that the vital activities of the adult beetles of the southern cowpea weevil, *Callosobruchus maculatus* F., living in warehouses, are dependable upon the inborn energy accumulated during their immature stages. This insect is also known to attack and breed successfully in many species and varieties of seeds which differ in their chemical constitution. It would thus seem interesting to test how far these different larval foods would affect the longevity and oviposition of the adults resulting therefrom.

Experiments

For this purpose, six widely different kinds of seeds were tried as rearing sources of the experimental insects. They were : red Canadian Wonder kidney beans (*Phaseolus vulgaris*), chick-peas (*Cicer arietinum*), broad windsor beans (*Vicia faba*), field peas (*Pisum sativum* var. *unica*), hyacinth beans (*Dolichos lablab*), and soyabeans (*Soja max* Piper). These seeds were first sterilized and then conditioned to 75% R.H. Each one-pound glass jar was half-filled with one kind of the mentioned seeds over which were introduced 20 newly-emerged adult beetles originally reared to maturity on blackeyed cowpeas at 25°C. and 75% R.H. All the jars, after being covered with muslin, were kept at the constant conditions of 25°C. and 75% R.H. The beetles therein were allowed to oviposit on the specific host-seed for a day's period after which the adults were discarded. Then the jars containing the egg-infested seeds were again kept constantly at 25°C. and 75% R.H. and were left undisturbed until the new generation of adult weevils appeared.

It was found that all the above-mentioned seeds, except the red kidney beans, produced adults. The whole developmental period from egg to imago stage took 38, 42, 49, 50, and 62 days, respectively, for individuals reared on chick peas, broad windsor beans, field peas, hyacinth beans, and soyabeans. Many adults emerged from the field peas, chick peas, and hyacinth beans; broad windsor beans produced less adults; and only few imagos were obtained from the soyabeans. Comparing the adults emerging from these kinds of seeds with the normal ones reared on the preferred host (black-eyed cowpeas), it was noticeable that the chick peas gave normal adults; while the field peas, broad windsor beans, and hyacinth beans each produced adults which were smaller and paler than the normal ones. The adults resulting from soyabeans were much smaller in size and of rather dull colour.

Repeated trials failed to produce adults from the red kidney beans. This kind of seed, though receiving numerous eggs which gave rise to young

larvae, the latter, however, died soon after hatching. On examination it was found that the hatched larvae had succeeded in boring through the seed-coat but died prior to penetrating the seed-bulb. It seemed that the newly hatched larva consumed its available energy in forcing its way through the thick testa of the seed that nothing was left to carry it through the more rigid seed-bulb and thus dying before attaining any appreciable size.

As soon as the adults started emerging in the other five jars, 25 male-female pairs of newly-emerged beetles were taken from each culture. One male and one female were confined together in a 2×1 inches specimen tube containing five blackeyed cowpeas conditioned at 75% R.H., and the tube covered with muslin. Blackeyed cowpeas were provided as oviposition site in all cases, irrespective of the host from which the adults were derived. The 25 tubes of every series were included in a separate desiccator maintained at 75% R.H., and all the desiccators were kept constantly at 25°C. The five cowpea seeds used as oviposition site for each tube were removed and replaced by fresh ones every day, and separate daily egg-counts were made for each female until death of the parent adults occurred; thus, permitting of a comparison of the daily and total oviposition in the different series. By recording the dates of emergence of the parent adults, of starting and stopping of egg-laying, and of death, it was possible to calculate the longevity of the weevils and the durations of the three oviposition periods.

The following is a summary of the results obtained for these experiments presented in the following sequence of the seeds used for rearing the adults to maturity : *Cicer arietinum*, *Vicia faba*, *Pisum sativum*, *Dolichos lablab*, and *Soja max*. The mean longevity per male was 12.60, 12.60, 10.92, 11.76, and 8.40 days, with a least significant difference of 1.37 between means. The mean longevity per female was 14.28, 13.16, 11.64, 12.08, and 9.28, with a least significant difference of 1.26 between means. The mean total number of eggs per female was 75.16, 60.92, 63.60, 58.32, and 45.72, with a least significant difference of 5.97 between means. The mean pre-oviposition period was null in all cases. The mean oviposition period was 11.12, 8.92, 8.92, 7.96, and 6.76 days, with a least significant difference of 0.96 between means. The mean post-oviposition period was 3.16, 4.24, 2.72, 4.12, and 2.52 days, with a least significant difference of 0.87 between means.

The different kinds of seeds were also chemically analysed. The following are the percentages of the essential ingredients of the seeds in the same sequence mentioned before. Water : 9.50, 10.86, 9.91, 13.10, and 8.11; crude protein : 18.40, 25.23, 25.58, 21.48, and 30.85; soluble carbohydrates : 56.21, 52.15, 54.54, 53.71, and 23.81; ether extract : 5.38, 1.41, 0.73, 0.50, and 19.44; crude fibre : 6.73, 7.12, 6.50, 7.49, and 11.54; ash : 3.78, 3.23, 2.74, 3.72, and 6.25.

Discussion

(1) The effect of food during the larval stages upon the longevity of the resultant adults

In spite of the many widely varied and chemically different varieties and species of seeds that are known to be fit for rearing a certain Bruchid to maturity, very few attempts have been made to investigate the effect of these different kinds of larval foods on the longevity of the resulting adults. In fact, no such trails were ever made on the southern cowpea weevil, *Callosobruchus maculatus* F.

Chiu and McCay (1939) cited Herford (1935) studying the influence of different larval foods upon the life of the adult of the bean weevil, *Bruchus obtectus* Say (= *Acanthoscelides obsoletus* Say), and finding that the chemical composition of the different species of seed used had a great effect on the activities of the subsequent adults; the optimum food being that which had a high carbohydrate content. The same insect was also subject to larval-feeding experiments made by Zazou (1948) who found that weevils reared on different kinds of host-seeds (white kidney beans, red kidney beans, black V beans, pea beans, lima beans, peas, and haricot beans) had different longevities, and that apart from the weevils reared on haricot beans which had the highest longevity, the differences between the longevities of those reared on the rest of seeds were not significant. However, a comparison based upon the chemical constitution of the different hosts had not been attempted. Attempts to determine the necessary food factors for the same insect had been carried out by Chiu and McCay (1939). Their method consisted essentially of modifying the normal food of the weevil (red kidney beans, *Phaseolus vulgaris*) by extraction or addition of various factors. Using finely-ground bean powder as a stock, six different diets were prepared, each being pressed into small pellets. Their results indicated that the weevil could not grow in an ether extracted normal diet, and that Cotton seed oil did not supply all the essentials removed by ether. They also found that the larva could grow but failed to complete its development in a fat-free normal diet in the presence of vitamin A or A and D; vitamin B₁ appeared to be essential. The weevil was found able to complete its development, but at a very slow rate, in an ether-extracted normal diet if 3% cholesterol were added to it, which indicated that a sterol may be essential for the development of this species.

In the present work carried out on *Callosobruchus maculatus* F., the analyses of variance of the data obtained on the longevity of the adult males and females, as affected by the different kinds of larval seed-foods, showed that the effect was very highly significant statistically. It is seen from the summarized

results given before that the adult weevils of either sex which were reared to maturity on the different species of seeds had different average longevities.

However, it is seen also that the most pronounced differences in the average longevities are those between weevils reared on soyabeans and all the other weevils reared on the rest of seeds; the differences proved all to be highly above the levels of significance calculated for the experiment (1.37 days in case of males and 1.27 days for females).

When we consider the chemical analyses of the seeds used as larval food we find that the carbohydrate content is very low in the soyabeans (23.81%) as compared with its value in all the other seeds (varying from 56.21 to 52.15%). This very low carbohydrate content in the soyabeans would probably account for the very pronounced reduction in the duration of life of the weevils emerging therefrom, the amount of energy stored up in the larval stages being poor and, consequently, a much shorter duration of adult life is to be expected.

Examining the average longevities of weevils reared to maturity on the rest of seeds other than the soyabeans, we find that the differences between them are all, except the few cases stated afterwards, insignificant statistically. This is also to be expected since the carbohydrate content is seen to be almost identical in those seeds.

The few cases in which the differences between the average longevities of the weevils lie above the levels of significance calculated are the following : chick peas-field peas, male 1.68 day, female 2.64 days; chick peas-hyacinth beans, female 2.20 days; broad beans-field peas, male, 1.68 day, female 1.52 day.

These exceptional cases are unexplainable on a sound basis under the present analyses of the food constituents. Probably, the higher fat content in the chick peas and broad beans than in the field peas and hyacinth beans would partly account for the longer life durations of the weevils reared on the former seeds than those reared on the latter seeds. Indeed, a more detailed analyses of the seeds in question are needed before a definite interpretation could be given. It is possible that some other nutritive factors, such as amino acids or vitamins, are involved.

(2) The effect of food during the larval stages on oviposition

Rearing certain Bruchids in different varieties and species of seeds is known to affect the oviposition of the resultant females. Z a a z o u (1948) cited M e n u s a n (1935) concluding that females of *Acanthoscelides obsoletus* reared on different varieties of beans would not oviposit at the same rate or give the same number of eggs. The same result for the same insect was obtained by Z a a z o u (1948) himself, who also added that the seven

varieties of seeds used could be divided into two distinct groups according to the number of eggs laid by the females reared on them. The first group, which produced females laying a very high number of eggs, included pea beans, white kidney beans, red kidney beans, and black valentine beans. The second group, which contained lima beans, haricot beans, and garden peas, produced females having a lower egg-production.

For the southern cowpea weevil, *Callosobruchus maculatus*, in spite of the great many seeds in which it was successfully bred to maturity, practically nothing has been done on the effect of these different larval foods on the oviposition of the resulting females. The only reference that has been met with in this respect was that of L a r s o n (1927). This author, during his extensive work on the application of the host-selection principle to this weevil, succeeded in breeding it for many successive generations on certain many kinds of seeds; while in other kinds of seeds, the insect could not reach maturity or the infestation died out after few generations. As an example of the latter case, L a r s o n reported some varieties of soyabeans in which the larval development was so retarded under favourable temperature that at least twice the normal time was required and the emerging adults being quite small and with low egg-production. In the soyabeans, L a r s o n had been unable to get more than three generations to develop. In trying to explain this finding he advanced the following : "Retarded development of the larval stages within soyabeans appears to be due to one of the two causes; first, the inability of the larvae to obtain sufficient food, and second the lack of some necessary element. If the latter were the chief cause it would seem that a very much greater percentage would die in the first stage; that only a very few would reach the second stage. However, it appears that more larvae die in the second stage and in each succeeding stage than die in the first larval stage. The writer interprets this to indicate the inability of the second stage larvae to sufficient food. The first stage larvae are able to get sufficient food because their prothoracic plates are better developed and used more in this stage than in any other. In this stage the use of these plates enables the larvae to hold the body firmly in the desired position while food is being obtained. In the later stages the larvae depend less on these plates and more on the rest of the body. The body appears to be unable to hold firmly in position within the cavity of the oily soyabean. The body with the less functional prothoracic plates skid so to speak, causing the larvae to die of slow starvation or to develop slowly. The emerging adults are reduced in vigor and vitality and produce only a few eggs so that a heavy infestation dies out in a few generations".

In the present work, the rearing of the southern cowpea weevil on five different kinds of seeds also showed that the development was considerably more retarded on the soyabeans than on any other seed. The chemical

analyses of the seeds presented before might explain this retardation as being due to both reasons mentioned before by L a r s o n . The "skidding" of the larvae and their subsequent inability to get sufficient quantity of food is expected owing to the much higher fat content of the soyabeans. The low percentage of carbohydrates contained in the soyabeans might also point to the deficiency in this necessary food element.

The average daily egg-production of a female reared to maturity on each kind of seed indicated that all females showed the same tendency towards heavy daily rate of egg-laying during the first few days and a steady decrease in the number of daily eggs as the females became older. In the female reared on soyabeans, however, the daily rate of egg-production was lower than that of females reared on the other seeds.

The analyses of variance of the results obtained on the total number of eggs laid by females reared on the different seeds indicated that the effect due to different larval feedings was very highly significant statistically. Considering the average total egg-productions presented before we find that the highest number of eggs was laid by a female reared on chick-peas (75.16 eggs), followed in order by that reared on field peas (63.60), bread windsor beans (60.92), hyacinth beans (58.32), and soyabeans (45.72). Since the least significant difference as calculated for the experiment is about 6 eggs, the females could be classified according to their average total egg-production into three categories. The first comprises the female reared on chick peas which produced the highest number of eggs. The second category includes the females reared on field peas, broad windsor beans, or hyacinth beans, which had an intermediate egg-production. The female reared on soyabeans constitutes the third category in which the lowest number of eggs was laid.

The chemical analyses of chick peas, field peas, broad windsor beans, and hyacinth beans show that these seeds are almost identical in their essential food elements except that the chickpeas contain a higher fat content than the others. This higher fat content of the chickpeas might possibly account for the higher egg-production of the female reared on it; the higher the fat content available to the larvae the greater the "egg-developing substance" stored and a consequent higher productivity of the female to emerge is what is to be expected. On the other hand, the poor carbohydrate content of the soyabeans and the inability of the larvae to get sufficient food in this oily seed means a lesser storage of egg-developing substance and emergence of a weak female that deposits fewer eggs, which is in fact observed.

No differences were observed in the pre-oviposition period of the females reared to maturity on the different seeds; this period being nill in all cases.

The analysis of variance of the oviposition periods of the females as affected by the different kinds of larval feedings indicated that the effect was highly significant statistically. It is seen from the figures given before that

the female reared to maturity on chickpeas, in which the egg-production was highest, has the longest oviposition period (11.12 days), while this period is 6.76 days in the lowest productive female reared on soyabeans. In the female reared on the other seeds, which had an intermediate productivity, the oviposition period is also of intermediate duration.

The analysis of variance of the data obtained on the post-oviposition periods of the females reared on the different kinds of seeds indicated that the effect due to the different larval feedings was highly significant statistically. The figures given before for the post-oviposition periods do not permit of definite deductions due to their irregularity. The safest conclusion to be drawn from the present results is that the post-oviposition period is lowest in the shortest-living females reared on soyabeans.

VII. THE EFFECT OF POPULATION DENSITY ON THE ADULT LONGEVITY AND RATE OF REPRODUCTION

The density of population, or the number of insects included together in a given space, proved, in many instances at least, to be one of the most significant environmental factors which bring about definite and remarkable effects upon the various biological functions of the constituent members of the population. Therefore, it was intended to test the influence of different population densities of the southern cowpea weevils upon the longevity and productivity of the concerned individuals.

TABLE VII

The effect of population densities of 2, 4, 8, 16, 32, and 64 upon the longevity of the adults of Callosobruchus maculatus F.

(Experimental insects reared and kept during adult life at 25°C. and 75% R.H.).

	AVERAGE LONGEVITY (IN DAYS) TO EACH OF THE FOLLOWING DENSITIES					
	1♂+1♀	2♂♂+2♀♀	4♂♂+4♀♀	8♂♂+8♀♀	16♂♂+16♀♀	32♂♂+32♀♀
First ♂ to die	9.8	9.2	7.9	7.5	6.6	5.8
Last ♂ to die	—	10.4	11.2	13.20	13.2	15.0
First ♀ to die	11.1	9.9	8.0	8.5	7.1	6.8
Last ♀ to die	—	12.3	11.5	14.5	14.5	15.4
All ♂♂ collectively	9.8	9.8	9.375	10.175	9.55628	9.8125
All ♀♀ collectively	11.1	11.1	9.70	10.8625	10.5875	10.6375
Average longevity for all weevils kept together.	10.45	10.45	9.5375	10.5175	10.075	10.225

Experiments

- (1) To determine the effect of population density on the longevity of

the adults of this Bruchid, six different densities were tried, in each of which half the population were males and the other half females. The densities used were 2, 4, 8, 16, 32, and 64 beetles, respectively, per a 4×1 inches specimen tube which was half-filled with sound sterilized blackeyed cowpeas conditioned at 75% R.H. The utilization of equally-sized cowpeas made the number required to half-fill such a specimen tube amount to 30 seeds. In this way, the tubes employed were exactly alike in every respect except for the number of insects they contained, i.e., the population density. Ten such tubes were made of each density of population except the last (i.e., density 64) which was repeated but five times due to lack of the necessary number of weevils.

The experimental insects used were all reared to maturity on blackeyed cowpeas at the constant conditions of 25°C. and 75% R.H., and were obtained unmated just on emerging by the method described in the technique.

All the tubes of the different population density series, after being covered with muslin, were kept constantly at 25°C. and 75% R.H. throughout the experiment. The contained seeds were not changed at all, and daily examinations were made in search for dead weevils which were immediately sexed and removed. Mortality records were kept until the death of the last weevil in every tube occurred.

The results of these experimental series are summarized in Table VII.

(2) In studying the influence of population density upon the rate of reproduction, the latter variable was intended to be measured by the average number of adult beetles produced per mated female per day over the actual oviposition period, or, namely, by measurement of the effective reproductive rate.

Six experimental environments were prepared in such a way that the initial population density, or the original number of weevils per gram of blackeyed cowpeas, was arranged in the following geometrical succession : 0.067, 0.134, 0.268, 0.536, 1.072, and 2.144 weevils, respectively. This was accomplished by weighing 60 lots, of 30 grams each, of sterilized blackeyed cowpeas previously conditioned at 75% R.H. The use of cowpea seeds of almost the exact size permitted that the same weight (30 grams) being given by the same number of cowpeas (90 seeds). Each lot of 90 seeds was put in a $6 \times 1\frac{3}{4}$ inches specimen tube. The 60 tubes, each of which containing 30 grams (or 90 seeds) of cowpeas, were divided into six series of ten tubes each. In each tube of the first series were put two weevils; the tubes of the second series received four adults each; while in the tubes of series 3, 4, 5, and 6, respectively, were introduced 8, 16, 32, and 64 beetles per tube. In every tube of the different series the population consisted of equal numbers of males and females. The adult beetles utilized were all unmated, immediately-emerged and taken from cultures reared on blackeyed cowpeas at the constant

conditions of 31°C. and 75% R.H. The experimental insects, being introduced in the concerned tubes, the latter were covered with muslin and kept all the time at a temperature of 31°C. and a relative humidity of 75%. The beetles in each tube were left to oviposit undisturbed until they all died when they were discarded, and then the egg-progeny was kept at the mentioned conditions until the adults started emerging from the cowpeas. From that time onwards, the adult progeny produced per each tube of every series were counted and removed daily until the emergence of no more weevils. The total number of adults obtained in each case gave the nett reproductive rate at each density.

The results of these experimental series are summarized in Table VIII.

Discussion

(1) The effect of population density on the adult longevity

Of the references dealing with the density effect upon the longevity, the following examples might be desirably cited.

TABLE VIII

A summary of the effect of population densities of 2, 4, 8, 16, 32, and 64 upon the fertility of the females of Callosobruchus maculatus F.

(Conditions during rearing and experiment kept at 31°C. and 75% R.H.).

	DENSITIES					
	1♂+1♀	2♂♂+2♀♀	4♂♂+4♀♀	8♂♂+8♀♀	16♂♂+16♀♀	32♂♂+32♀♀
Weight in grams of cowpea-seeds.	30	30	30	30	30	30
Initial number of weevils.	2	4	8	16	32	64
Weevils per gram of cowpea.	0.067	0.134	0.268	0.536	1.072	2.144
Number of cowpeas per female.	90	45	22.5	11.25	5.625	2.8125
Number of adult progeny produced.	25.80	61.70	120.6	299.2	598.1	599.7
Number of adult progeny per female.	25.80	30.85	30.15	37.40	37.38	18.74
Number of progeny per female-day.*	5.16	6.17	6.03	7.48	7.48	3.75

*Calculated on the basis that the oviposition period at such condition was found to be 5 days approximately.

Pearl, Miner and Parker (1927), in their experimental studies on *Drosophila*, came to the conclusion that the rate of mortality of the adults was profoundly influenced by the number of flies occupying together a limited universe in which the volume of air, volume of food, and area of food surface were constant. They also found that, under the particular conditions of their experiments, there was an optimal density of population falling somewhere in the region of 35 to 55 flies per one-ounce bottle containing

8cc. of food substrate. Any change in density below or above this optimum resulted in higher specific death rates at all ages.

It has been shown by Z a a z o u (1948) that the longevity of the adult bean weevil, *Acanthoscelides obsoletus*, was much affected by density. Using either unmated males or unmated females, each at densities ranging from 1 to 7 beetles per tube, he found that the longevity of the first weevil to die decreased as the density of population increased; whereas the last weevil to die showed an increase in longevity as the number of weevils kept together increased from 1 to 6, but when the density was increased from 6 to 7 there was a decrease in longevity. As for the collective average longevity of all the weevils kept together, there was an increase in this longevity as the density increased from 1 beetle per tube to an optimum of 6, above which the more increase to 7 caused a decline in the longevity.

Indeed, no studies were carried out before on the effect of population density upon the longevity of the adults of *Callosobruchus maculatus*. The results of the present work dealing with the effect of densities of 1, 2, 4, 8, 16, and 32 male-female pairs upon the longevity (Table VII) showed that, under the present conditions of the experiment, i.e., constant 25°C. and 75% R.H., and the 4 × 1 inches tube containing 30 blackeyed cowpeas, there was an optimum density of population. This proved to be the one in which 8 pairs of weevils were kept together, since in this density the average longevity of all the weevils collectively is seen to be highest (10.52 days). The change of the number of weevils kept together above or below this optimal density is seen to affect their average total longevity causing it to decrease in both cases. It is also apparent from Table VII that the density effect manifests itself on the life duration of the first weevil to die differently than it does on the last weevil to die; the longevity in the first case is inversely proportional to the density, while in the second case it varies with the density.

A plausible explanation for the decrease in the average total longevity under conditions of intense crowding may be that the individuals come into physical contacts more frequently which leads to a greater excitation of the weevils and the cut down of the normal rest periods in both frequency and duration. It then follows that the energy output of the weevils in muscular work is exceedingly increased and, accordingly, their sooner death is what is to be expected.

At the densities below the optimum, it is rather difficult to explain the cause of the decrease in the average total longevity of all the weevils. The effective factor in this case is suggested to be that the enclosure of a small number of the beetles in a comparatively wide space lessens the opportunities for copulation. This leads to an increased energy spent in one sex of the weevils seeking the other sex, with the result that the average life duration is decreased.

(2) The effect of population density on the rate of reproduction

It has long been known that the degree of crowding of organisms in a given volume or area of space is a factor of primary importance in shaping the course of growth of the population in numbers, because it produces a direct effect upon the rate of reproduction of the individuals composing the population. Pearl and Parker (1922) were perhaps the first to produce some quantitative evidence towards a true density effect in insects. Studying the effect of population density upon the effective reproductive rate of *Drosophila melanogaster* these workers found out that as the number of flies per half-pint containers was increased from 1 to 50 pairs, the number of adult offspring produced per female per day continuously decreased in an orderly manner; the falling off of the curve being extremely rapid at first, and then more and more slowly at higher densities. Further work carried out by Pearl (1932) on the same insect showed that fecundity (eggs laid per female day) diminished with increasing density of population, just as fertility (adult progeny produced per female day) was shown to do in the earlier work cited.

MacLagan (1932) made a valuable contribution to the subject by analysing the experimental data obtainable from the population studies of Chapman (1928) on *Tribolium confusum* and by carrying out additional experiments on the same insect and on *Calandra granaria*. He concluded that there was a striking decrease in the rate of reproduction as the population density was increased, and that there existed an optimum density at which was brought about the maximum reproductive rate.

The density effect in *Acanthoscelides obsoletus* has been studied by Zazou (1948) who came to the conclusion that the variables, population density and adult progeny per weevil per day, exhibited an inverse relationship. The rate of reproduction per female increased till a certain optimum density was reached, after which any increase in the population density caused a decrease in the rate of reproduction.

As to the southern cowpea weevil, *Callosobruchus maculatus*, nothing was done before on the effect of population density upon its rate of reproduction. This being presently investigated, the results (Table VIII) indicated that there was a profound change in fertility, as measured by the number of adults produced per female per day, with increasing density of population from 2 to 64 weevils per tube. Under the particular conditions of this experiment, the rate of reproduction per initial female per day increased regularly as the density was increased until an optimal density of 16 or 32 weevils kept together was reached after which any further increase in the population density caused a decrease in the number of adults produced per female per day. At this optimum density (8 or 16 male-female pairs) the number of adults pro-

duced per female-day was 7.84; while when 1, 2, or 4 pairs of weevils were, respectively, kept together the rate of reproduction amounted only to 5.17, 6.17, and 6.03, respectively. But, at the high population density of 32 pairs the number of progeny produced fell considerably to 3.75 adults per female-day.

This drop in the rate of reproduction at the higher density of population may at first sight be attributed to mere larval and pupal elimination due to overcrowding and inadequacy of food in these stages. But careful examination of the results of Table VIII reveals that this is not the cause. Observing the absolute figures of the average total numbers of progeny produced at the different densities, we find that the highest figure obtained is 599.7, which was produced when 16 mated females were originally kept together in the same tube containing 90 cowpea-seeds. In other words, an average of 6.7 adults emerged from every cowpea seed. Anyone who has experimentally bred the southern cowpea weevil must have observed that as many as eleven adults could be produced from a single cowpea seed, i.e., the food contained in one seed is sufficient for eleven larvae to develop through and give rise to adults. This indicates that many more adults than 599.7 could have been produced in the tube with the 90 seeds and 16 mated females had it not been for the density effect. Therefore, the larval and pupal elimination due to overcrowding should not be the cause for the decrease in the number of progeny.

The most reasonable explanation for the drop in the reproductive rate at densities above the optimum appears to be that the crowding of large numbers of weevils together in the same limited space increases the chances of their coming into physical contacts with each other with the result that each individual female being continuously interrupted in her attempts to oviposit and thus does not lay her normal output of eggs. There are also the increased chances of interference with the act of copulation so that when it does occur it is too late in the life of the female to result in normal productivity. Direct observations reinforce these conclusions.

As to the interpretation of the reduced reproductive rate at densities below the optimum, it is not unreasonable to assume that the effective factor here is the decreased opportunities for physical contacts which at least stimulate, if not essential to, the act of copulation. This would undoubtedly lead to a delay in the occurrence of mating which results in a decrease in the normal productivity of the individual females.

Besides mere physical density effects, it is believed by Pearl and Parker (1922) that there is another element involved in the existence of an optimum reproductive rate. They claim this factor to be the psychological effect resulting from keeping a number of individuals together in a confined space; the population density operating organically through

a psychological reaction which adversely affects the physiological process of reproduction.

It would appear, therefore, that natural populations of the southern cowpea weevil check their own increase by virtue of the density effect, and that the insect itself imposes the ultimate limit to its own abundance even when all other biotic and physical factors are ideal for the population increase.

VIII. THE EFFECT OF OVIPOSITION - SITE ON THE LONGEVITY AND OVIPOSITION

The presence or absence of seeds is certainly a decisive factor that affects the oviposition of stored product insects of which the southern cowpea weevil is one. Also, the latter insect has been observed during the course of its rearing to avoid egg-laying on broken or uncoated cowpeas. How far the presence or absence of cowpea seeds, their condition, whether whole or split into pieces, coated or with testa removed, would affect the longevity and rate of oviposition of the adult females, seemed to be an interesting problem and formed the substance of the experimental series hereafter described.

Experiments

Four series of ten 2×1 inches specimen tubes each were prepared. Each of the ten tubes of the first series received five whole sound cowpeas. In every tube of the second series were introduced five halves of longitudinally-split seeds with their testa intact. The tubes of the third series received each five half-seeds from which the seed-coats were removed. No seeds at all were put in any of the tubes of the fourth series. Into each tube of the different series were introduced a male and a female of newly-emerged adults which were reared to maturity on blackeyed cowpeas at constant 25°C . and 75% R.H. The tubes were then covered with muslin and kept constantly at 25°C . and 75% R.H. Substitution of the oviposition site with a fresh one and replacement of the vacant tubes by clean ones were practiced daily. Egg-counts were made daily in each tube until the adults died. Care was taken throughout the experiment that the muslin and tube walls be carefully examined in search of eggs. Records were also made of the dates of emergence and death of the adult weevils; hence, the longevities were known. By recording the dates of starting and stopping of egg-laying, the three oviposition periods were also determined.

It was observed that as long as seeds were present as oviposition site, there were no eggs deposited on the muslin cover or on the walls of the tubes. In cases where the seeds were half-split, whether coated or uncoated, oviposition occurred only on the outer convex side of the halved seed, while the internal concave side never received any eggs.

The following is a summary of the results of these experiments in the following sequence of oviposition sites : whole sound cowpeas, half-split cowpeas with testa intact, half-split cowpeas with testa removed, and vacant vials (with no seeds). The mean female longevity was 10.30, 12.20, 12.70, and 15.10 days, with a least significant difference of 2 between means. The average total eggs produced was 69.9, 64.4, 55.8 and 34.2, with a least significant difference of 10.58 between means. The mean pre-oviposition period was 0.20, 0.20, 2.20, and 1.1 days, with the least significant difference of 0.47 between means. The oviposition period was 8.10, 9.20, 8.80, and 10.50 days, with the least significant difference of 1.44 between means. The post-oviposition period was 2.0, 2.8, 3.7, and 3.50 days, the differences between the means being insignificant statistically.

Discussion

(1) The effect of oviposition site upon the adult female longevity

The only reference that had been come across related to the influence of oviposition site on the longevity of the adult Bruchids was that of *Larson* and *Fisher* (1938). Speaking of the bean weevil, *Acanthoscelides obtectus*, and the southern cowpea weevil, *Callosobruchus maculatus*, they stated : "..... weevils that do not have seeds on which to oviposit do not live as long as those with the seeds".

The analysis of variance of the results of the present investigations on the effect of the different kinds of oviposition site on longevity of the females of *Callosobruchus maculatus* indicated that the effect was very highly significant statistically. Considering the average longevities presented before, we find that the differences which lie above the least significant level of 2 days calculated for the experiment are those between all the treatments except between halved seeds with the testa intact and halved uncoated seeds where the difference between the average longevities is only 0.5 day. The most striking effect of the oviposition site, however, is seen to be in the much longer longevity of the female that is wholly deprived of seeds than that of the female living among whole sound cowpeas. Obviously, this is contrary to *Larson* and *Fisher's* statement that the weevils not having seeds on which to oviposit were shorter-lived than those with the seeds.

The longer duration of life of the female living among abnormal oviposition sites or with no oviposition seeds at all than that of the female having access to the preferred oviposition site (whole tightly-coated cowpeas) might be accounted for on the "rate of living" theory of life duration. According to this theory, the greater the expenditure of energy in egg-production during the oviposition period, as indicated by the daily rate, the shorter the duration of life of the female. This is actually what happened in the

present experiment, because the average daily oviposition per female was found to decrease in the following order : female with whole sound cowpeas, female with half-split coated cowpeas, female with half-split coatless cowpeas, and lastly female without any seeds. Actually this is the order to which the female longevity is seen to be inversely proportional.

(2) The effect of oviposition site on the productivity

The oviposition site is known to affect the productivity of the Bruchids in general. The presence or absence of beans or cowpeas has been found by Larson and Fisher (1938) to act as a stimulus to oviposition of the bean weevil and the southern cowpea weevil. These writers arrived at this conclusion by placing pairs of weevils in vials without seeds and others in vials with seeds and finding that, although mating occurred in both sets of vials, practically no eggs were deposited in those without seeds, whereas many eggs were laid in the vials with seeds. Writing on the oviposition of *Callosobruchus maculatus* in storage they stated also that the female certainly avoided seeds having broken or loose seed-coats, but that she laid her eggs only on unbroken seeds with smooth, well-fitted coats.

In the present experiment, the measurement of the average daily number of eggs deposited per female under these different oviposition sites indicated that the rate of daily oviposition was far much lower in the vials receiving no seeds than in the vials with seeds. It was evident also that in the vials containing the different oviposition-seeds the number of eggs deposited per day decreased regularly with the age of the female; whereas in the vials with no seeds there was an irregular intermittence of high and low egg-production per successive days of oviposition.

The analysis of variance of the results obtained on the effect of the different kinds of oviposition site upon the total number of eggs laid per mated female indicated that the effect was highly significant statistically. It is seen from the figures given before that the total number of eggs deposited per female having no access to seeds for oviposition was very much lower than that deposited by other females having access to seeds whether sound or split, coated or uncoated. This is in agreement with the finding of Larson and Fisher that the presence of seeds acts as a stimulus to oviposition. It is seen also that using only split, coatless seeds for oviposition caused a significant reduction in the total number of eggs deposited as compared to that laid in the presence of whole sound seeds. This might account for the marked predilection of females to oviposition on whole seeds having unbroken, well-fitting coats.

The analysis of variance of the figures obtained on the pre-oviposition periods showed that this period was very significantly affected by the different oviposition sites. It is seen from the figures given before that as long

as seeds, whether sound, split, or split and uncoated, were available to the weevils the pro-oviposition period remained unaltered and was almost nil. But, in the absence of seeds the pre-oviposition period was considerably increased to more than one day. This might be explained on the supposition that the presence of seeds acts as a stimulus towards early oviposition; the female kept without seeds tending to withhold her eggs for a longer period than do the female kept with seeds. Another possible explanation is that the presence of seeds acts as a stimulus to copulation, and their absence leads to a retardation in the occurrence of mating with the result that the egg-deposition is consequently delayed.

The analysis of variance of the data obtained on the oviposition periods of the females as affected by the different oviposition sites showed that the effect was significant statistically. It is evident from the figures given before that the use of the different oviposition sites resulted in some differences in the duration of the oviposition period. But, as the least significant level calculated for the experiment is 1.44 day, it is seen that the only differences that are significant statistically are those between the oviposition period of the female kept without seeds and that of the female with whole seeds (difference = 2.4 days), and between the oviposition period of the females kept in vacant vials and that of the female kept with split uncoated seeds (difference = 1.7 days). This significant increase in the oviposition period of a female kept without seeds over that of a female kept with whole sound seeds or with split uncoated seeds might be accounted for by the previously observed lower rate of daily egg-deposition in the first case than in the second or third case, which means a lower energy expenditure and a consequent longer oviposition period.

The analysis of variance of the data obtained on the post-oviposition periods indicated that the effect due to the different oviposition sites was insignificant statistically. It is, therefore, concluded that the different kinds of oviposition sites used had no effect at all on the post-oviposition period of the female.

IX. THE EFFECT OF MATING ON THE LONGEVITY, OVIPOSITION AND EGG-INCUBATION.

The longevity of adult insects, their oviposition, and the hatching of their eggs are known to be largely affected by the process of copulation. Therefore, it was thought advisable to test the effect of mating on the adult duration of life, on the daily and total number of eggs laid, and on the length of the three oviposition periods of *Callosobruchus maculatus*. The viability of the parthenogenetically-laid eggs was also intended to be investigated.

Experiments

To investigate the effect of mating on the above variables, 50 unmated males and 50 virgin females were individually obtained just on emergence by the method described in the technique. They were all reared to maturity on blackeyed cowpeas at the constant conditions of 25°C. and 75% R.H.

Three sets of twenty five 2×1 inches specimen tubes each were prepared, and in each tube were introduced five blackeyed cowpea seeds previously conditioned to 75% R.H. In each tube of the first set was put an unmated lone male. The tubes of the second set received each an unmated lone female; whereas in each of the remaining 25 tubes were confined a male and a female. The tubes, after being covered with muslin, were kept all constantly at 25°C. and 75% R.H. until all the weevils died. The cowpeas were replaced daily by fresh ones in the tubes containing the lone females and the couples, and daily records were made of the eggs found on the discarded seeds. The longevity of every weevil was also recorded.

The following is a summary of the results of these experimental series giving the figures for the unmated adults first followed by those of the mated ones: mean longevity of males 19.16, 10.72 days; mean longevity of female 21.88, 10.80 days; average total number of eggs per female 3.76, 80.08; mean pre-oviposition period 15.32, 0.0 days; mean oviposition period 3.0, 7.64 days; mean post-oviposition period : 3.56, 3.16 days.

The eggs laid parthenogenetically by the isolated virgin females were kept at the same conditions of temperature and humidity to find out whether they hatched or not.

In addition, an unmated female and a virgin female were put together as soon as they emerged in each of twenty five 2×1 inches specimen tubes which were kept under careful observation at room temperature (about 24°C.) and registrations were made of the durations of the act of copulation.

Discussion

(1) The effect of mating on the longevity of the adults

The longevity of adult insects as influenced by the process of mating has been investigated by several authors. To give examples, Lund (1938), experimenting on the parasite *Trichogramma evanescens*, found that the longevity of females given host eggs immediately upon emergence was unaffected by pairing or virginity. The males, however, which were denied the opportunity to mate until they were 48 hours old lived significantly longer than males paired immediately upon emergence.

For the bean weevil, *Acanthoscelides obsoletus*, Bushnell and Boughton (1940) found that there was a slight tendency for the unmated

males and females to live longer than mated ones, but that the differences were not great to be significant statistically. Working on the same insect, Z a a z o u (1948) found that unmated weevils of both sexes lived longer than mated ones; the longevity of unmated males being 13.4 ± 2.1 days as opposed to 13.2 ± 1.7 days in mated males, and the corresponding figures for unmated and mated females being 16.2 ± 2.4 and 14.7 ± 2.7 days, respectively.

For *Drosophila*, H a n s o n and F e r r i s (1929), as cited by B u s h n e l l and B o u g h t o n (1940), found out that virgin females have, on the average, a life span 14.8 days longer than mated females.

For the southern cowpea weevil, *Callosobruchus maculatus*, L a r s o n and F i s h e r (1924) showed that the virgin females lived longer than the mated ones receiving the same treatment as to food, and that the virgin females which did not receive food were unable to live as long as those receiving water, honey, or sugar-water.

The results given before of the present investigations on the longevity of the adults of *Callosobruchus maculatus* as affected by mating or unmating showed that the unmated weevils of either sex lived significantly longer than mated ones. The unmated males lived an average of 19.16 days, or 8.44 days longer than did the mated ones. For the unmated females the average longevity was 21.88 days as opposed to 10.80 days in the mated ones, or with a difference of 11.08 days in favour of the unmated females. The present results are, therefore, in general accordance with the findings of L a r s o n and F i s h e r for the same insect.

This very pronounced increase in longevity of unmated weevils over mated ones can be interpreted on suggesting that pairing results in an increased energy expenditure in finding the other sex, in the act of copulation itself, and in egg-laying, which shortens the life span of the individuals.

It might be noteworthy at this point to mention a few words about the process of mating and its duration in the southern cowpea weevil. B r a u e r (1925) stated that copulation takes place shortly after emerging. Writing about the same insect, L a r s o n and F i s h e r (1938) claimed that mating may occur under storage conditions any time from a few hours to a few days after emergence, and that in warm weather it takes place almost immediately after emergence. These writers also mentioned P a d d o c k and R e i n h a r d (1919) quoting that a pair of this weevil has been noted in copulation one minute after emerging, and that the process of copulation was generally of short duration, rarely comprising more than 3 or 4 minutes. They stated also that their own observations indicated that the duration of copulation was from 5 to 34 minutes, the period being shortest while the male was young and vigorous.

The present writer's observations are in harmony with the above find-

ings. Mating has been observed to take place readily as soon as the male and the female were put together just after emergence from the seed. At room temperature of about 24°C., the act of copulation in 25 pairs of immediately-emerged weevils has been found to last for from 4 to 21 minutes, with a mean duration of 8.66 minutes.

(2) The effect of mating or unmating on the productivity and the incubation of the eggs

The profound effect of mating on egg-deposition in insects is well-known. Few instances may be appreciably cited here. Virgin females of the bean weevil, *Bruchus obtectus*, have been shown by Menusan (1935) to lay only one-fifth the number of eggs of fertile females. In addition, he mentioned that all the eggs deposited by virgin females collapsed soon after deposition. Experimenting on the same insect, Bushnell and Boughton (1940) noted that the mated females laid 1.56 times as many eggs as did the unmated ones.

Lund (1938) quoted Hanson and Ferris (1929) finding that mated females of *Drosophila melanogaster*, a species which does not reproduce parthenogenetically, laid from 1.6 to 2 times more eggs than did virgins; the presence of the male stimulating oviposition..

On the other hand, in those insect species that have parthenogenetic habits, the effect of mating is different. For example, the results of pairing experiments carried out by Lund (1938) on the hymenopterous egg-parasite *Trichogramma evanescens* indicated that there was a definite increase in the number of progeny when the females remained virgins throughout their lives. Lund's conclusion was that the presence of the male evidently in some way inhibited oviposition. That the mere presence of another insect, rather than the disturbance caused by the act of copulation itself, was responsible for the lower productivity of paired females was suggested by the fact that the presence of a second female having the same effect as the presence of a male. The average productivity was 67.1 in female-female pairs; 81 for virgin females individually isolated; and 66.1 for female-male pairs.

For the effect of mating on the productivity of *Callosobruchus maculatus*, the results of Larson and Fisher's (1924) feeding experiments showed that virgin females fed on water, honey, sugar-water, or nothing, laid an average of 0.33, 1.17, 0.83, and 0.50 eggs, respectively, per individual; the corresponding figures for mated females were 114.88, 119.88, 132.16, and 88.52 eggs, respectively. These authors also stated that none of these parthenogenetically-laid eggs had hatched. Also, Brauer (1925) reported the unfertilized females depositing during their lives a far less number of eggs than did the fertilized females.

The present results on the effect of mating and unmating on the

productivity of the southern cowpea weevil showed that a very marked difference in the rate of daily egg-laying existed between the mated and unmated females. There was a tendency towards heavy daily egg-production during the first four days of the mated female. The latter also reached the peak of her egg-production on the first day after emergence, after which the daily egg-production gradually tapered off as the mated female grew older until it stopped completely by the eleventh day. The unmated female tended to withhold all her eggs until the eighth day after emergence. From this eighth day to the 25th. day after emergence, there was an irregular very low rate of egg-laying per day by the unmated female. The mated female at her peak, on the first day, had laid an average of 23.52 eggs; whereas the maximum number of eggs laid in one day (the 15th) by the unmated female was on the average 0.48 egg only.

The results of the total number of eggs laid by the unmated and mated females indicated that the maximum total number of eggs an unmated female had laid during her life was 17 eggs; while the maximum egg-production per mated female reached to 104 eggs. It was evident also that a number of the unmated females did not lay any eggs, while the minimum number of eggs laid by a mated female was 55. It was found that the average total eggs deposited per unmated female was 3.76 as compared with 80.08 for the mated female; the latter having laid 21.3 times as many eggs as did the unmated one. Evidently, this conclusion coincides with that stated by *Larson* and *Fisher*, and by *Brauer*.

The dissection of the mated females after their death revealed that they have laid almost all their capacity of eggs, while the unmated ones were found to withhold enormous numbers of undeposited eggs in their ovaries. This indicates that copulation acts as a stimulus to the deposition of eggs.

In confirmity with *Larson* and *Fisher*'s finding, it has been found that all the eggs laid by virign females collapsed soon after deposition and failed to hatch.

Regarding the pre-oviposition period of the females as affected by mating or virginity, it is evident from the figures given before that the period was very significantly longer in the unmated females than in the mated ones; the average duration of that period being 15.32 days in the unmated female, while it was nill in the mated one.

The data obtained on the effect of mating on the oviposition period indicated that this period ranged in virgin females from 0 to 8 days; whereas in mated females the range was 5 to 10 days. The average oviposition period was found to be 3 days in the unmated females, as compared with an average period of 7.64 days in the mated females. This shows that oviposition is stretched over a very significantly longer period in the mated females than in the unmated ones.

The data obtained on the post-oviposition period as affected by mating or unmating showed that whereas this period ranged from 0 to 13 days in virgin females, with a mean of 3.56 days, it lasted for from 2 to 8 days, with an average of 3.16 days, in the mated females. The difference in the average duration of the post-oviposition period between the two groups proved to be insignificant statistically.

Therefore, the general conclusion is that as well as egg-laying is very markedly delayed in the unmated female, her oviposition period is also very much reduced as compared with that of the mated female. But, the post-oviposition period shows almost the same duration for both the mated and unmated females.

X. THE EFFECT OF TEMPERATURES AND HUMIDITIES ON THE DURATIONS OF THE DEVELOPMENTAL STAGES

It is well known that the temperatures and humidities to which the developmental stages of an insect are exposed have a great influence upon the durations of these stages. As to the southern cowpea weevil, *Callosobruchus maculatus* F., very little experimental work has been done on the effect of temperature and humidity on its developmental periods; the only observed contribution in this connection was that of Schoof (1941) who dealt with the influence of different levels of humidities, at one constant temperature of $30 \pm 0.8^\circ\text{C}.$, on the durations of the immature stages. Therefore, it was thought appreciable to study the effects of different combinations of temperatures and humidities upon the egg-incubation period, larval-pupal period, and the egg-larval-pupal period of the mentioned Bruchid.

Experiments

To fulfill the above purpose, several series of experiments were conducted at five different constant temperatures and four different controlled relative humidities. The temperatures used were 18, 21, 25, 31, and $35^\circ\text{C}.$, each of which was maintained with each of the following humidities : 55, 65, 75, and 90% R.H. Under each of the above 20 environmental conditions was put a one-pound glass jar containing 50 sterilized cowpea seeds previously conditioned to the necessary humidity. On the 50 seeds of each jar were sprinkled 5 newly-emerged mated females of the southern cowpea weevil. All the females used were taken from a culture reared to maturity on blackeyed cowpeas at the constant conditions of $25^\circ\text{C}.$ and 75% R.H. The females of each jar were left to oviposit on the contained seeds for a day after which the adults were removed and discarded. Then the seeds of every jar with the eggs borne on them were taken and only one egg was allowed to stay on every cowpea, the rest of eggs on the seed being removed. Thus, from every

experimental series were available 50 eggs each of which was borne solely on a cowpea seed. Each seed with its egg was then put separately in a $1 \times 1\frac{1}{2}$ inch specimen tube. The 50 tubes of every experimental series were then maintained constantly at the required combination of temperature and humidity, and were put under constant observation until the eggs hatched and the adults emerged. Records were made of the dates of egg-laying, incubation

TABLE IX

Summary of the incubation period and the larval-pupal period (in days) of Callosobruchus maculatus F., as affected by different temperatures at different levels of humidities (Means of days for 50 individuals).

HUMIDITY TREATMENTS	TEMPERATURE TREATMENT MEANS										MEAN PER INSECT	
	18°C.		21°C.		25°C.		31°C.		35°C.			
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
55% R.H.	20.70	119.88	10.96	47.86	7.22	41.74	3.98	20.32	3.68	15.68	9.308	49.096
65% R.H.	20.80	119.22	10.76	47.32	7.04	36.08	3.98	20.28	3.66	15.52	9.248	47.684
75% R.H.	20.60	118.52	10.68	46.74	6.94	32.98	3.98	18.28	3.72	14.66	9.184	46.236
90% R.H.	20.74	—	10.60	—	6.76	—	3.94	—	3.68	—	9.144	—
MEAN PER INSECT	20.71	119.20	10.75	47.307	6.99	36.933	3.97	19.627	3.685	15.287	9.221	47.672

(1) (2)

L.S.D. (P=5%) between means of temperature = 0.1093 1.8023

L.S.D. (P=5%) between means of humidity = 0.0978 insignificant.

(1) = Incubation period of egg; (2) = larval-pupal period.

N.B. : At 90% R.H. in all temperatures all larvae and pupae died due to the extensive growth of fungi.

of the egg, and emergence of the imago. Hence, the incubation period, the larval-pupal period, and the whole developmental period from egg to adult were determined under the different combinations of temperatures and humidities. Sexing every adult on emergence allowed for a comparison of the above-mentioned periods in both sexes.

The results obtained for the different experimental series are summarised in Table IX.

Discussion

(1) The effect of combined temperature and humidity on the incubation period of the eggs

(a) The effect of temperature.

Extensive experimental work on various insects has been done on the

duration of the egg-stage in relation to different constant temperatures. The greater body of evidence points to the existence of an optimal temperature at which the eggs hatch in the shortest time; any change in the temperature above or below this optimum lengthens the incubation period. To illustrate this, the following example might be cited. Menusan (1934) found that the optimum temperature for the bean weevil eggs was approximately 30°C. Increasing the temperature to 34°C. increased the time required for the eggs to hatch; but at 38 or 40°C. the eggs were either killed or did not develop to any appreciable extent. The lowest constant temperature at which the eggs hatched was 13.9°C.

The effects of different constant temperatures upon the incubation period of the eggs of the southern cowpea, *Callosobruchus maculatus*, have not been studied, though several observations in this connection were made. Brauer (1925) stated that under the most favourable conditions (unstated) the larva emerged in about 100 hours after the deposition of the egg. Larson and Fisher (1938) presented a Table showing the duration of the egg-stage at different times of the years 1926 and 1927 under the weather conditions that prevailed in Alhambra, California. This Table showed that the duration of the egg-stage varied with the temperature; the variance being 3 days for those eggs laid in August to 27 days for those laid in December. These authors also referred to Paddock and Reinhard (1919) giving a Table of the egg-incubation period in Texas in which the shortest time recorded was 3 days (in September) and the longest being 37 days in the middle of the winter.

In the present work, the analysis of variance of the data obtained on the incubation period as affected by the different combinations of temperatures and humidities clearly indicated that the effect due to temperature changes was exceedingly highly significant statistically. It is apparent from the summarized results given in Table IX that the gradual increase in the temperature caused a significant reduction in the time required for the eggs to hatch; the mean incubation period being 20.71, 10.75, 6.99, 3.97, and 3.685 days, respectively, at temperatures of 18, 21, 25, 31, and 35°C. The differences between these periods are seen to be highly above the level of significance calculated for the experiment (0.11 day).

Concluding, it can be said that the optimum temperature for the hatching period is 35°C. The gradual decrease below this temperature results in a corresponding delay in the speed of metabolism in the egg-stage. However, the increase in the duration of the egg-stage with the drop in the temperature is much more pronounced at the lower temperatures than at the higher ones.

The rate of decrease in the incubation period with the rise of the temperature from 21 to 31°C. is $10.75/3.97 = 2.7$; while from 25 to 35°C. the rate is $6.99/3.685 = 1.9$. In other words, the rate is nearly doubled with

every ten degrees rise in temperature, i.e., the Van't Hoff's rule for chemical reactions holding good for the speed of metabolism in the egg-stage of the southern cowpea weevil.

(b) *The effect of humidity*

There is evidence in the literature that the duration of the egg-stage is sometimes longer in dry air than in moist air. For example, Headlee (1917) stated that the length of the egg-incubation period of the bean weevil, *Bruchus obtectus*, was 6 days in saturated air and only 4 days in air of 23.6% R.H., the temperature being standardized at 80°F. Menusan (1934) also reported a similar increase in the duration of the egg-stage of the same insect at 25.2°C. and humidities ranging from 50 to 95%; the optimum humidity being, however, at 90% R.H.

There is also some evidence that the eggs of insects that normally live in dry environments are either unaffected or that dry air shortens the duration of the egg-stage. Thus, Menusan (1934) cited Holdaway (1932) showing that, apart from the absence of hatching in a saturated atmosphere, due to development of fungi, the eggs of *Tribolium confusum* were not affected by a change in atmospheric moisture.

The role played by moisture on the incubation period of the egg of *Callosobruchus maculatus* has been studied by Schoof (1941) at a constant temperature of $30 \pm 0.8^\circ\text{C}$. His experiments indicated that the duration of the egg-stage calculated to the time that 75% of the eggs hatched showed a slight but steady decrease from 5.3 to 4.2 days when the humidity was increased from 0-3 to 63%. At humidities of 80 and 91% the period was lengthened to 4.3 and 4.6 days, respectively; thus placing the optimum humidity around 63%.

The analysis of variance of the results of the present investigations on the effect of constant relative humidities of 55, 65, 75, and 90%, at five different temperatures, upon the incubation period of the egg of the southern cowpea weevil showed that the effect due to humidity changes was highly significant statistically. The summarized results presented in Table IX indicate that when the eggs are placed at 55, 65, 75, and 90% R.H. they hatch in 9.308, 9.248, 9.184, 9.144 days, respectively. The differences between these successive periods are seen to be insignificant statistically since they are all below the least significant difference calculated for the humidity treatment in this experiment (0.1 day). But, it is also obvious that the immediate increase in humidity from 55 to 75%, from 55 to 90%, or from 65 to 90%, caused a statistically significant decrease in the time required for hatching, since the differences in these mentioned cases are above the level of least significance.

The ultimate conclusion, therefore, is that the optimum humidity for the hatching of the southern cowpea weevil's egg is 90% R.H. Decreasing the relative humidity from 90 to 65% or more, and from 75 to 55%, resulted in a slight but statistically significant increase in the incubation period of the egg.

The present results agree with those of Schoof in the general trend that the speed of metabolism in the egg-stage of *Callosobruchus maculatus* varies with the humidity; but, while the optimum humidity has been found in this work to be at 90% R.H., it proved with Schoof to be at 63% R.H.

(2) The effect of combined temperatures and humidities on the larval-pupal period.

(a) The effect of temperature

The general conception is that for every insect there exists for the development of the larva and pupa an optimum temperature, above or below which the duration of these stages is lengthened. As an example, Menusan (1934) found that, at 90% R.H., the optimum constant temperature for the development of the larval-pupal stage of the bean weevil, *Acanthoscelides obtectus*, was approximately 30°C. At this temperature the adult males emerged in 23 days, and the females in 24 days. Increasing the temperature to 34 or lowering it to 27°C. increased the length of time required for the emergence of the adults. Further gradual decrease in the temperature to 17.6°C. resulted in further lengthening of the larval-pupal period.

As to *Callosobruchus maculatus*, nothing has been done on the effect of temperature upon the duration of the larval-pupal stage. Only few observational remarks have been made in this respect. The following is a quotation from Larson and Fisher (1938): ".....the duration of the larval stage varies not only with temperature and humidity but also with the hosts in which they are developing. It has been observed to range from 9 days (Paddock and Reinhard, 1919) or less (Breitenbecher, 1923) to 8 months (Larson and Simmons, 1923)... During warm weather in California the larval stage lasts from 17 to 22 days". In the same paper they quoted: "The duration of the pupal stage, like that of the other stages of the weevil, varies greatly according to the temperature. A few degrees' difference in mean temperature makes a very noticeable difference in the duration of this stage. The writers have not noted as short, or as long, duration of this stage as are recorded by Paddock and Reinhard (1919), who recorded extremes of 3 and 53 days. They show not only that the mean temperature may have a positive effect on the length of the pupal stage but that the average length of the stage may be influenced by a severe low temperature or by a few days of warm weather. Larson and

S i m m o n s (1923) noted that the duration of all later stages may be influenced by a period of cold or warm weather during the first few days after the eggs have been laid”.

The analysis of variance of the results of the present investigations on the effect of five different temperatures, at four different humidities, upon the larval-pupal period of the southern cowpea showed that the effect due to temperature changes was very highly significant statistically. It is seen from Table IX that at temperatures of 18, 21, 25, 31, and 35°C., respectively, the mean duration of the larval-pupal stage was 119.207, 47.307, 36.933, 19.627, and 15.287 days, respectively. The differences between these durations are seen to be all above the least significant difference calculated for the temperature effect (1.8 day). Therefore, it is concluded that, as was the case with the egg-incubation period, 35°C. is the optimum temperature for the development of the larval-pupal stage. Decreasing the temperature gradually below this temperature results in a continuous increase in the larval-pupal period; the increase, however, being much more marked in the lower temperatures than at the higher ones.

Considering now the rate of decrease in the duration of the larval-pupal stage with every ten degrees rise in the temperature, we find that when the temperature is increased from 21 to 31°C. the rate of increase in the period equals to $47.307/19.627$ or 2.41, and from 25 to 35°C. the rate is $36.933/15.287$ or 2.42. The conclusion then is that the speed of development in the larval-pupal stage is nearly doubled by every ten degrees' rise in the temperature, or the speed is of the same order of magnitude as that required by V a n ' t H o f f s' rule for chemical reactions.

(b) *The effect of humidity.*

The few workers who dealt with the larval-pupal period of Bruchids are seemingly agreed in that the speed of metabolism in that stage varies inversely with the humidity. To give an example, M e n u s a n (1934) showed for the bean weevil, *Acanthoscelides obtectus*, that, at 25.2°C., the duration of the larval and pupal stages increased as the humidity was increased; the duration gradually varied from 26 and 27 days at 98% to 42 and 44 days at 10% R.H. for males and females, respectively.

Similarly, the study carried out by S c h o o f (1941) on the effects of several relative humidities ranging from 0.3 to 91%, at a temperature of $30 \pm 0.8^\circ\text{C}$. upon the larval-pupal period of *Callosobruchus maculatus* indicated that the duration, calculated to the time that 50% of the adults emerged, showed a decrease from 21.1 days at 0.3% R.H. to 16.6 days at 80% R.H. But, at 91% R.H. the duration was increased to 17.7 days. The mortality of the larval-pupal stages has been found to be approximately the same at humidities from 0.3 to 80% R.H., but at 91% R.H. the mortality was signifi-

cantly higher than at all other humidities.

The results of the present investigations on the effect of relative humidities of 55, 65, 75, and 90%, at five different temperatures, upon the duration of the larval-pupal stage showed that at 90% R.H., with all temperatures, practically no adults emerged due to the destruction of the larvae and pupae by the extensively growing fungi. This made it obligatory to exclude all the results of the 90% R.H. at all temperatures from the statistical analysis of the data. The analysis of variance of the rest of data indicated that the effect due to humidity increase was insignificant statistically. However, it is seen from Table IX that the larval-pupal period is lengthened as the humidity is lowered gradually from 75 to 55% R.H., though the increase is not significant statistically.

Therefore, the conclusion is that, for the larval-pupal period of *Callosobruchus maculatus*, the optimum humidity is 75%. Any increase or decrease in humidity from this optimum, though resulting in an increase in the duration of this period, yet this increase is statistically insignificant. This is in partial agreement with the previously mentioned findings of Schoof for the same insect.

(3) The effect of combined temperatures and humidities on the egg-larval-pupal period

Regarding the duration of the egg-larval-pupal stages, considered as one unit, as affected by the different combinations of temperatures and humidities, it can be concluded from Table IX that the whole developmental period is decreased as the temperature is increased gradually from 18 to 35°C.

As to the effect of humidity, it can be concluded from the same Table that the optimum humidity for the egg-larval-pupal period is 75% R.H. Schoof (1941), working on the effect of various relative humidities, at $30 \pm 0.8^\circ\text{C}$., upon the whole developmental period of the same insect, arrived at the same conclusion, with only one difference that he found the optimum humidity to be at 90% R.H.

The results of the present experiments about the whole developmental period in either sex showed also that the average time required for the development of the males was, in the majority of cases, only a fraction of a day less than that required for the females. Larson (1927) also stated that they males and females emerging from eggs laid on the same day showed little or no difference in the rate of development.

XI. THE EFFECT OF COMBINED TEMPERATURES AND HUMIDITIES ON ADULT EMERGENCE AND SEX-RATIO

The experimental work that has been done in insects on the effect of

constant temperatures and humidities upon the number of adults emerging from the egg-progeny and upon the sex-ratio is, seemingly, quite rare. In fact, all the studies that have been made in this respect on the southern cowpea weevil, *Callosobruchus maculatus* F., were carried out either under natural weather conditions (Larson and Simmons, 1923, and Larson and Fisher, 1938) or under different humidities at one constant temperature (School, 1941). The percentage of adult emergence and the sex-ratio in the resulting progeny, being factors of great importance not only to the economy of the southern cowpea weevil but also for its control, it was intended in the present work to find out how far they would be affected by different combinations of constant temperatures and humidities.

Experiments

To study this effect several series of experiments were conducted at five different constant temperatures and four different controlled relative humidities. The temperatures used were 18, 21, 25, 31, and 35°C. Each of these temperatures was combined with each of the following humidities : 55, 65, 75, and 90% R.H. The adult parent insects used in all these 20 series of experiments were all reared to maturity on blackeyed cowpeas at the constant conditions of 25°C. and 75% R.H. A male-female couple of newly-emerged adults were put in a 2×1 inches specimen tube containing five blackeyed cowpeas previously conditioned to the relative humidity intended to be used in the specific series of the experiment. The tube was then covered with muslin secured by rubber band. For every experimental series 15 of such tubes were made and placed in a desiccator at the required humidity, and the desiccator then put at the temperature wanted.

Every tube of every experimental series was examined each morning, the eggs counted, and the contained seeds substituted by fresh ones, until the death of the parent female. All the eggs laid by each female during the life-time were left on their supporting host-seeds which were put in a separate glass tube. The individual tubes of each experimental series were kept undisturbed at the required temperature and humidity until the emergence of adults started. On emergence, the adults produced were sexed daily and removed, and records were made of the number and sex of the resulting adults. This was continued until the adults ceased to emerge from the corresponding cowpeas.

Comparing the total number of adult progeny produced by the females of each series to the total number of eggs they have originally laid, the average percentages of adult emergence were obtained under the different combinations of temperatures and humidities. These percentages proved to be as shown in the following Table.

For every experimental series separately, the number of adult-male

RELATIVE HUMIDITY PERCENTAGE	18°C.	21°C.	25°C.	31°C.	35°C.	MEAN PERCENTAGE
55	57.51	78.39	87.69	84.96	89.24	79.56
65	65.59	79.03	85.64	79.24	88.76	79.65
75	57.87	82.53	85.76	84.18	87.37	79.54
90	6.77	19.28	17.43	81.46	80.00	40.99
MEAN %	46.93	64.81	69.13	82.46	86.34	69.93

progeny emerged was divided by the whole number of adults produced; and by multiplying the resulting figure by 100, the sex-ratio in the resultant progeny was obtained. The average sex-ratios obtained under the different combinations of temperatures and humidities were as follows :

RELATIVE HUMIDITY PERCENTAGE	18°C.	21°C.	25°C.	31°C.	35°C.
65	50.49	50.57	52.92	52.43	52.98
65	52.45	50.81	51.24	51.52	52.41
75	51.24	50.33	51.13	51.91	53.42
90	—	—	—	52.69	52.82

Discussion

As to the percentage of adults emerging from the egg-progeny of females of *Callosobruchus maculatus* F., Larson and Simmons (1923) found that, under natural conditions of California, an average of 55% of all the eggs produced by mated females succeeded in reaching the adult stage; the highest percentage of producing adults out of the eggs of one female being 81 and the lowest 25%. The experiments of Schoof (1941) which were carried out on the same insect at constant $30 \pm 0.8^\circ\text{C}$. and different relative humidities showed that there was no significant difference between the percentage of adults emerging at 44, 63, and 80% R.H., but that humidities below and above these points did produce significant reduction in the percentage of adult emergence.

Under weather conditions prevailing in California, Larson and Simmons (1923) found that the emerged adults which resulted from the eggs of 61 females of *Callosobruchus maculatus* were found to be nearly equally divided as to sex; 52% being males and 48% females. Working on the same insect, under laboratory conditions, Larson and Fisher (1924) investigated the sex-ratio in the adult progeny produced from 25 mated females fed on nothing, water, honey, or sugar. They found that the sexes were about equally divided; the 1514 emerged weevils from the group not fed being 753 males and 731 females; the 1870 from the water-fed group were 926 and 944; the 1836 from the honey-fed group were 919 and 917; and those

from the sugar-fed group were 1077 males and 1044 females. Thus, of the 7341 emerged weevils 50.47% were males and 49.53% were females. Writing on the sex-ratio of this insect in another paper, Larson and Fisher (1938) quoted the following : "Although Prichard and Breitenbecher (1925) showed that theoretically there should be equal numbers of males and females of *Callosobruchus maculatus*, the writers have observed that there is a preponderance of males. With favorable food in which to develop, from 52 to 59% of the beetles usually are males. In less favorable food, the males percentage has been observed to be even higher."

In the present investigations, it was evident, as seen from the figures presented before, that the percentage of adult production increased progressively as the temperature was increased from 18 to 35°C. On the other hand, whereas at the relative humidities of 55, 65, and 75% there was no change in the percentage of adults emerging, the further increase of the humidity to 90% R.H. resulted in a profound reduction in the percentage of adult production due to the extensive growth of fungi which were fatal to large numbers of the larvae and pupae.

The present results about the effect of humidity upon the percentage of adult emergence are, evidently, in general accordance, but differ in detail from those found out by Schoof.

The percentage of emerged adult males to the total adult progeny produced at each of the different combinations of temperatures and humidities are presented before. The figures for the 90% R.H. with temperatures 18, 21, and 25°C. were omitted from the Table due to the very low adult progeny produced (as a result of the extensive growth of fungi) which undoubtedly would otherwise lead to deceiving sex-ratios. It is seen from the given figures that both the temperature and humidity apparently have no effect on the sex-ratio in the resulting adults. At all the temperatures and humidities used, the sex-ratio is seen to be approximately 1 to 1, with a slight preponderance of males; the average percentage of the latter being within the range of 50.33 and 52.98. This finding coincides with the results obtained by the previously mentioned workers on the sex-ratio.

XII. SUMMARY

(1) In Egypt, the loss in weight to cowpea seeds due to the southern cowpea weevil infestation, during 3 months only, amounted to more than 51.3%.

(2) There were eleven generations a year under weather conditions prevailing in Egypt.

(3) At the standard reading conditions of 25°C. and 75% R.H., and using constant temperatures of 18, 21, 25, 31, and 35°C., respectively, with relative humidities of 55, 65, 75, and 90%, during the imaginal stage of *Callosobruchus*

maculatus, it was found that :

(a) The longevity of the adults of both sexes decreased as the temperature was increased. At all the temperatures the females lived longer than the males; this difference being more pronounced at 18°C. than at the higher temperatures. In both sexes the adult longevity was nearly halved by every 10°C. rise in temperature.

(b) The adult longevity progressively increased as the relative humidity was increased. This was true for both males and females, without any difference between the sexes as to the sensitivity to changes in humidity.

(c) The highest number of eggs was laid at 25°C. (optimum). Any change in the temperature above or below this optimum resulted in a considerable decrease in the number of eggs laid per female. The pre-oviposition period was nill at 21, 25, and 31°C., while at 18 and 35°C. it was significantly increased to 0.38 and 1.07 days, respectively. The oviposition period was significantly decreased by the gradual rise in temperature. Also, the higher the temperature the shorter the post-oviposition period was.

(d) The average total number of eggs deposited per female was slightly, but significantly, increased as the humidity was increased. The humidity had no effect on neither the pre- and post-oviposition periods, but the oviposition period increased as the relative humidity was increased.

(4) Using constant temperatures of 21, 25, and 31°C., respectively, each with constant relative humidities of 55, 65, and 75% R.H., respectively, during the immature stages of *Callosobruchus maculatus*, and under conditions standardized during adult life at 25°C. and 75% R.H., it was found that :

(a) The increase in the rearing temperature from 21 or 25 to 31°C. caused a decrease in the longevity of the resulting adults; the reduction being greater in the females than in the males.

(b) The humidity to which the eggs, larvae and pupae were exposed had no effect at all on the longevity of the subsequent adults.

(c) The total number of eggs deposited per female was very markedly reduced as the temperature at which the females were reared to maturity was lowered. The temperature of rearing did not affect the pre-oviposition period; this period being less than one day in all cases. The oviposition period decreased as the rearing temperature was increased. The post-oviposition period was longest at 25°C., and any change below or above this temperature resulted in a decrease in the period.

(d) The rearing humidity had no effect upon the total egg-production per female. The three oviposition periods were also unaffected.

(5) Using chick peas, broad Windsor beans, field peas, hyacinth beans, and soyabeans, respectively, as foods for rearing the adults of *Callosobruchus maculatus*, and at the standard conditions of 25°C. and 75% R.H. during development and adult life, it was found that :

(a) Adult weevils reared to maturity on the different species of seeds had different longevitys. In all cases the females lived longer than the males. The weevils reared on soyabeans had a significantly shorter life duration than that of those reared on any of the other seeds. This is probably accounted for by the much lower carbohydrate content of the soyabeans than in the rest of seeds, which results in a lesser amount of energy stored up in the larval stages and, consequently, a shorter life duration. The differences between the average longevitys of weevils reared on the rest of seeds other than soyabeans were, except in the few cases stated afterwards, insignificant statistically; this was expected since the carbohydrate content is almost identical in these seeds. The differences between the average longevitys of weevils reared on chick peas or broad windsor beans and those reared on field peas or hyacinth beans were found to be statistically significant; this may probably be accounted for by the higher fat content in the former seeds than in the latter ones.

(b) Females reared to maturity on chickpeas produced the highest total number of eggs, while those reared on soyabeans had the lowest egg-production. The quantity of eggs laid by females reared on field peas, broad beans, or hyacinth beans was intermediate. The higher fat content available to the larvae in the chickpeas might point to a greater storage of the "egg-developing substance" and a consequent higher productivity of the female to emerge. The poor carbohydrate content of the soyabeans and the "skidding" and inability of the larvae to get sufficient food in this oily seed might possibly account for the emergence of weak and low productive females. The pre-oviposition period was nil in all cases. The longest oviposition period was that of the highest productive female reared on chickpeas, and the shortest was that of the lowest-productive female reared on soyabeans. Females reared on the rest of seeds and having intermediate productivity had also an intermediate oviposition period. The post-oviposition period was shortest in the shortest-living female reared on soyabeans.

(6) All conditions being standardized (25°C. and 75% R.H.; 4×1 inches tubes containing 30 black-eyed cowpeas), and using population densities of 1, 2, 4, 8, 16, and 32 male-female pairs of weevils, respectively, it was found that the density of 8 pairs was the optimum or the one at which the average longevity of all the weevils collectively was longest. The change of the number of weevils kept together above or below this optimal density resulted in a decrease in the average longevity.

(7) At constant 31°C. and 75 %R.H., and using densities of 1, 2, 4, 8, 16, and 32 male-female pairs of beetles, respectively, per $6 \times 1 \frac{3}{4}$ inches tube containing 30 grams (or 90 seeds) of blackeyed cowpeas, it was found that the rate of reproduction, as measured by the number of adults produced per initial female per day, increased regularly as the density was increased from 2 weevils kept together to an optimum of 16 or 32 weevils per tube. Further increase

in the number of population above this optimal density caused a significant decrease in the rate of reproduction.

(8) All other conditions being standardized, and using as oviposition site whole sound cowpeas, half-split cowpeas with testa intact, half-split coatless cowpeas, or vials without seeds, respectively, indicated that :

(a) The females kept with the different oviposition sites showed different longevities. The life duration of the female deprived of seeds to oviposit on was much longer than that of one living among seeds whether sound or split, coated or uncoated.

(b) Females without seeds had a considerably lower total egg-production than that of those with seeds, whether sound, split, or coatless; the presence of seeds thus acting as a stimulus to oviposition. The removal of the seed-coat also lowered the egg-production of the female below that of one kept among seeds with unbroken, well-fitting coats. In the presence of seeds, whole or split, coated or uncoated, the pre-oviposition period was nill, but in the absence of seeds the pre-oviposition period was more than one day, thus indicating that seeds are stimulant to early oviposition, or that the absence of seeds retarding copulation so that oviposition is also delayed. The oviposition period was longer in the female without seeds than in another kept with seeds. The different kinds of oviposition sites had no effect on the post-oviposition period.

(9) Mating has been observed to take place in *Callosobruchus maculatus* soon after emergence of the male and female from the seed. At room temperature (about 24°C.) the act of copulation lasted for 4-21 minutes, with an average of 8.66 minutes.

(10) Investigating the effect of mating at constant 25°C. and 75% R.H. it was found that :

(a) The unmated males and females lived 1.79 and 2.03 times, respectively, as did the mated ones.

(b) The mated female gave the peak of her egg-production on the first day, after which the daily rate of egg-laying gradually tapered off as she grew older. The unmated female tended to withhold her eggs until the eighth day, after which there was an irregular very low daily-rate of egg-laying. The mated female laid 21.3 times as many eggs as did the unmated female. Mating acted as a stimulus to the female depositing her full capacity of eggs. The unmated female had a significantly longer pre-oviposition period than the mated female. The oviposition period was much longer in the mated than in the unmated female. The difference in the post-oviposition period between the mated and the unmated females was insignificant.

(c) All the parthenogenetically-laid eggs never hatched.

(11) Using constant temperatures of 18, 21, 25, 31, and 35°C., respectively, each with constant relative humidities of 55, 65, 75, and 90%, respectively,

it was found that :

(a) The gradual increase in temperature resulted in a progressive decrease in the time required for the eggs to hatch. The incubation period was reduced by a rate of about two with every 10°C. rise in temperature. The immediate increase in humidity from 55 to 75% or higher, or from 65 to 90%, caused a significant decrease in the hatching period.

(b) The duration of the larval-pupal stage was also considerably reduced as the temperature was progressively increased; the period being nearly halved by every 10°C. increase in temperature. The optimum humidity for the larval-pupal period was 75% R.H.; any change in humidity below or above this optimum reduced the duration of this period, but the increase was insignificant statistically.

(c) The egg-larval-pupal period decreased as the temperature was increased. The optimum humidity for the whole developmental period from egg to adult was 75% R.H.; any change from it increased the period. The average time required for completing the development of the male was a fraction of a day less than that required for the female.

(12) Using constant temperatures of 18, 21, 25, 31, and 35°C., respectively, each with constant relative humidities of 55, 65, 75, and 90%, respectively, on *Callosobruchus maculatus*, it was found that :

(a) The percentage of adult emergence increased progressively as the temperature was increased. At relative humidities of 55, 65, and 75% there was no change in the percentage of adult emerging; but at 90% the percentage was profoundly reduced due to growth of fungi.

(b) Temperatures and humidities had no effect on the sex-ratio in the emerged adult progeny. There was always a slight preponderance of males; 50.33 to 52.98% of the progeny being males.

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XIV. BIBLIOGRAPHY

- Allee, W. C. (1931) : Animal aggregation (The University of Chicago Press).
- Allee, W. C.; Emerson, A. E.; Park, O.; Park, Th.; and Schmidt, K. P. (1949) : Principles of Animal Ecology (Saunders Company, Philadelphia and London).
- Alpatov, W. W. (1930) : Experimental studies on the duration of life. XIII. The influence of different feeding during the larval and imaginal stages on the duration of life of the imago of *Drosophila melanogaster* (Amer. Nat., LXIV, no. 690, pp. 37-55).
- Alpatov, W. W. (1932) : Egg-production in *Drosophila melanogaster* and some factors which influence it (J. Exp. Zool., LXIII, no. 1, pp. 85-111).
- Alpatov, W. W., and Pearl, R. (1929) : Experimental studies on the duration of life. XII. Influence of temperature during the larval period and the adult life on the duration of the imago of *Drosophila melanogaster* (Amer. Nat., LXIII, no. 684, pp. 37-67).
- Azab, A. K. (1953) : The effect of various types of food upon the rate of development of the larvae of *Stegobium paniceum* L. [Coleoptera, Anobiidae] (Bull. Soc. Fouad I Entom., XXXVII, pp. 127-147).
- Azab, A. K. (1953) : The influence of yeast upon the rate of development of the larvae of *Stegobium panicum* L. [Coleoptera, Anobiidae] (Bull. Soc. Fouad I Entom., XXXVII, pp. 149-165).
- Baumberger, J. P. (1914) : Studies on the longevity of insects (Ann. Ent. Soc. Amer., VII, pp. 323-353).
- Bliss, C. I. (1927) : The oviposition of the grape leaf-hoppers (J. Agric. Res., XXXIV, no. 9, pp. 847-852).
- Bodenheimer, F. S. (1938) : Problems of Animal Ecology (Oxford University Press).
- Brauer, A. (1925) : Studies on the embryology of *Bruchus quadrimaculatus* F. (Ann. Ent. Soc. Amer., XVIII, no. 3, pp. 283-312).
- Breitenbecher, J. K. (1926) : Variation and heredity in *Bruchus quadrimaculatus* Fabr. [Coleoptera] (Canad. Ent., LXIII, no. 6, pp. 131-133).
- Bridwell, J. C. (1929) : The cowpea Bruchid [Coleoptera] under another name. A plea for one kind of Entomological specialist (Proc. Entom. Soc. Wash., XXXI, no. 2, pp. 39-44).
- Brindley, T. A., and Hinman, F. G. (1937) : Effect of growth of

- Pea Weevil on weight and germination of seed peas (*J. Econ. Ent.*, XXX, no. 4, pp. 664-670).
- Bushnell, R. J., and Boughton, D. C. (1940): Longevity and egg-production in the common bean weevil, *Acanthoscelides obtectus* (Say) (*Ann. Ent. Soc. Amer.*, XXXIII, no. 2, pp. 361-370).
- Buxton, P. A. (1931): The measurement and control of atmospheric humidity in relation to entomological problems (*Bull. Entom. Res.*, XXII, part 3).
- Chiu, Shin Foon, and McCay, C. M. (1939): Nutritional studies of the confused flour beetle (*Tribolium confusum* Duval) and the bean weevil (*Acanthoscelides (Bruchus) obtectus* Say) (*Ann. Ent. Soc. Amer.*, XXXII, no. 1, pp. 164-170).
- Crombie, A. C. (1941): On oviposition, olfactory conditioning and host-selection in *Rhizopertha dominica* Fab. [Insecta, Coleoptera] (*J. Exp. Biol.*, XVIII, no. 1, pp. 62-79).
- Crombie, A. C. (1942): The effect of crowding upon the oviposition of grain-infesting insects (*J. Exp. Biol.*, XIX, no. 3, pp. 311-340).
- Headlee, T. J. (1917): Some factors relative to the influence of atmospheric humidity on insect metabolism (*J. Econ. Ent.*, X, no. 1, pp. 31-38).
- Headlee, T. J. (1921): The response of the bean weevil to different percentages of atmospheric moisture (*J. Econ. Ent.*, XIV, no. 3, pp. 264-269).
- Herford, G. M. (1935): Observations on the biology of *Bruchus obtectus*, with special reference to the nutritional factors (*Z. angew. Ent.*, XXII, no. 1, pp. 25-50).
- Imms, A. D. (1932): Temperature and humidity in relation to problems of insect control (*Ann. Appl. Biology*, XIX, no. 2, pp. 125-143).
- Larson, A. O. (1924): The effect of weevily seed beans upon the bean crop and upon the dissemination of weevils, *Bruchus obtectus* Say and *B. quadrimaculatus* Fab. (*J. Econ. Ent.*, XVII, no. 5, pp. 538-548).
- Larson, A. O. (1926): Observations on the characteristic injury caused by the Lima Bean Pod Borer, *Etiella zinckenella* Treit., and other insects with which its injury is confused in California (*J. Econ. Ent.*, XIX, no. 5, pp. 699-703).
- Larson, A. O. (1927): The Host-selection principle as applied to *Bruchus quadrimaculatus* Fab. (*Ann. Ent. Soc. Amer.*, XX, no. 1, pp. 37-79).
- Larson, A. O., and Fisher, C. K. (1924): Longevity and fecundity of *Bruchus quadrimaculatus* as influenced by different foods (*J. Agric. Res.*, XXIX, no. 6, pp. 297-305).
- Larson, A. O., and Fisher, C. K. (1924): The possibilities of weevil development in neglected seeds in warehouses (*J. Econ. Ent.*, XVII, no. 6, pp. 632-637).
- Larson, A. O., and Fisher, C. K. (1925): The role of bean straw stack

- in the spread of bean weevils (*J. Econ. Ent.*, XVIII, no. 5, pp. 696-703).
- Larson, A.O., and Fisher, C.K. (1938) : The Bean Weevil and the Southern Cowpea Weevil in California (*Tech. Bull. U.S. Dept. Agric.*, no. 593, 70pp.).
- Larson, A.O., and Simmons, P. (1923) : Notes on the biology of the four-spotted bean weevil, *Bruchus quadrimaculatus* Fab. (*J. Agric. Res.*, XXVI, p. 609).
- Lepesme, P. (1944) : Les Coloéptères des denrées alimentaires et des produits industriels entreposés (*Encyclopédie Entomologique*, XXII, pp. 198-219).
- Loeb, J., and Northrop, J.H. (1916) : Is there a temperature coefficient for the duration of life ? (*Proc. Nat. Acad. Sci. Wash.*, II, pp. 456-457).
- Lund, H.O. (1938) : Studies on longevity and productivity in *Trichogramma evanescens* (*J. Agric. Res.*, LVI, no. 6, pp. 421-439).
- MacArthur, J.W., and Baillie, W.H.T. (1929) : Metabolic activity and duration of life : I. Influence of temperature on longevity in *Daphnia magna*; II. Metabolic rates and their relation to longevity in *Daphnia magna* (*J. Exp. Zool.*, LIII, no. 2, pp. 221-268).
- MacLagan, D.S. (1932) : The effect of population density upon rate of reproduction with special reference to insects (*Proc. Roy. Soc. London (B)*, LXI, no. 773, pp. 437-454).
- Menusan Jr., H. (1934) : Effects of temperature and humidity on the life processes of the bean weevil, *Bruchus obtectus* Say (*Ann. Ent. Soc. Amer.*, XXVII, no. 4, pp. 515-526).
- Menusan Jr., H. (1935) : Effects of constant light, temperature and humidity on the rate and total amount of oviposition of the bean weevil, *Bruchus obtectus* Say (*J. Econ. Ent.*, XXVIII, no. 2, pp. 448-453).
- Menusan Jr., H. (1936) : The influence of constant temperatures and humidities on the rate of growth and relative size of the bean weevil, *Bruchus obtectus* Say (*Ann. Ent. Soc. Amer.*, XXIX, no. 2, pp. 279-288).
- Menusan Jr., H., and MacLeod, G. H. (1937) : Toxicity of high temperatures to Bean Weevil eggs (*J. Econ. Ent.*, XXX, no. 6, pp. 954-958).
- Oosthuizen, M.J. (1940) : The Cowpea Weevil (*J. Ent. Soc. Sthn. Afr.*, III, pp. 151-158).
- Oosthuizen, M.J., and Laubscher, F. X. (1940) : The cowpea weevil (*J. Ent. Soc. Sthn. Afr.*, III, pp. 151-158).
- Pearl, R. (1932) : The influence of density of population upon egg production in *Drosophila melanogaster* (*J. Exp. Zool.*, LXIII, no. 1, pp. 57-84).
- Pearl, R., Miner, J. R., and Parker, S.L. (1927) : Experimental studies on the duration of life : XI. Density of population and life duration

- in *Drosophila* (*Amer. Nat.*, LXI, no. 675, pp. 289-318).
- Pearl, R., and Parker, S.L. (1922) : On the influence of density of population upon the rate of reproduction in *Drosophila* (*Proc. Nat. Acad. Sci. Wash.*, VIII, pp. 212-218).
- Raichoudhury, D.P., and Jacobs, S.E. (1937) : Experiments on the sterility of *Ephestia kuhniella* (Lepidoptera, Phycitidae), in relation to high temperature (30°C.) (*Proc. Zool. Soc. London*, (A), CVII, pp. 283-288).
- Richards, O.W. (1927) : Sexual selection and allied problems in the insects (*Biol. Rev.*, II, pp. 298-350).
- Rilett, R.O. (1946) : Desiccators as constant humidity chambers (*J. Econ. Ent.*, XXXIX, no. 3, p. 385).
- Schoof, H.F. (1941) : The effects of various relative humidities on the life processes of the southern cowpea weevil, *Callosobruchus maculatus* (Fabr.) at $30 \pm 0.8^\circ\text{C}$. (*Ecology*, XXII, pp. 297-305).
- Solomon, M.E. (1951) : Control of humidity with potassium hydroxide, sulphuric acid, or other solutions (*Bull. Ent. Res.*, XLII, no. 3, pp. 543-554).
- Thorpe, W.H. (1930) : Biological races in insects and allied groups (*Biol. Rev.*, V, no. 3, pp. 177-212).
- Uvarov, B.P. (1928) : Insect nutrition and metabolism (*Trans. Ent. Soc. London*, LXXVI, part 2, pp. 255-343).
- Uvarov, B.P. (1931) : Insects and Climate (*Trans. Ent. Soc. London*, LXXIX, part 1, pp. 1-247).
- Wade, O. (1919) : The four-spotted cowpea weevil (*Bruchus quadrimaculatus* Fab.) (*Okla. Agr. Expt. Sta.*, Bull. no. 129).
- Wigglesworth, V.B. (1950) : The principles of insect physiology (4th. edition, London).
- Zaazou, H.T. (1948) : The longevity of the bean weevil, *Acanthoscelides obsoletus* Say (*Bull. Soc. Fouad I Entom.*, XXXII, pp. 51-70).
- Zaazou, H.T. (1948) : Oviposition of the bean weevil, *Acanthoscelides obsoletus* Say (*Bull. Soc. Fouad I Entom.*, XXXII, pp. 343-361).
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Mosquitoes of north-eastern Sinai

[Diptera : Culicidae]

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This paper describes a collection of mosquito larvae made by the author while a member of the Egyptian Desert Institute expedition to the north-eastern part of Sinai. The survey was carried out during August 1951. The area surveyed extends northward from El-Arish west to Rafah east, and southward from Hassana west to Kossaima east.

DESCRIPTION OF THE AREA

The topography of the area is a plateau sloping gently to the Mediterranean. The climate is characterised by rainless warm summers and cool winters. The mean annual rainfall, temperature and elevations for four important centers within the area are :

LOCATION	ELEVATION IN METERS	RAINFALL IN MMS.	MEAN TEMPER- ATURE IN °C.	MAXIMUM TEMPER- ATURE IN °C. (1)	MINIMUM TEMPER- ATURE IN °C. (2)
El-Arish	10	97	19.5	30.6	7.3
Abu Aweigela	140	63	—	—	—
Hassana	250	55	—	—	—
Kossaima	330	37	—	—	—

Hottest month (August). — (2) Coldest month (January).

The water supply within the area consists of wells and springs. Two main types of wells exist :

(1) Shallow wells known by the arabs as Tamayel. Water can be obtained at a depth from 0.5 to 9 meters. This is common in the coastal area where the rain water percolates and collects in the sand dunes commonly present.

(2) Deep wells, here, rain water collects in relatively deeper strata in the wadies. The depth to the water bearing strata (known by

Arabs as Fagra) varies from 10 to 35 meters. Some of the existing deep wells have been visited at Rafah, near El-Arish, Hassana and Kossaima.

The water supply for Wadi El Gedeirat is from Ain El Gedeirat. Water flows naturally like a spring and is carried in iron pipes and cement canals to irrigate the area below. During the night, water is collected and stored in a reservoir of a capacity about 1000 cubic meters ($20 \times 20 \times 3.5$).

Agriculture in north-eastern Sinai is of the spotted type. Patches of cultivated land are found near the city of El-Arish, Rafah and at Wadi El Gederiat. The area of these farms varies from a fraction of a feddan to about 30 feddans. Barley and wheat are considered the two main crops grown on rain water. Around El-Arish, small orchards and vegetable farms flourish on supplemented irrigation from wells. Palm groves extend along the Mediterranean coast.

PREVIOUS MOSQUITO RECORDS FROM NORTH-EASTERN SINAI

Kirkpatrick (1925) in his account of the mosquitoes of Egypt, recorded twenty two species of mosquitoes. Out of these, only ten species (3 Anophelines and 7 Culicines) were reported from north-eastern Sinai. Saleh (1938) in his paper on the mosquito fauna of Sinai peninsula, recorded the following species from north-eastern Sinai: *Anopheles dthali* Patton, *Anopheles turkhudi* Liston, *Anopheles superpictus* Grassi, *Anopheles multicolor* Camb., *Anopheles sergenti* Theo., *Anopheles pharoensis* Theo., *Culex pusillus* Macq., *Culex laticinctus* Edw., *Culex sinaiticus* Kirkp., *Culex pipiens* Lin., *Culex laurenti* Newst., and *Culex theileri* Theo.

Of this list, *Anopheles pharoensis* Theo., *Culex pusillus* Macq., and *Culex laurenti* Newst. were not encountered in the present study. On the other hand, *Uranotaenia unguiculata* Edw., is reported here for the first time from Sinai and *Aedes (Ochlerotatus) caspius* Pallas is encountered for the first time from north-eastern Sinai. The latter species was reported by Kirkpatrick (1925) from Bir Fuwara east of Ismailia, and that was its only record from Sinai. *Culex univittatus* Theo. also encountered in the present survey, was reported by Kirkpatrick under the name *Culex perexiguus* Theo. from El-Arish in north Sinai.

BIOLOGY AND DISTRIBUTION OF SPECIES UNDER STUDY

Anopheles (Myzomyia) superpictus Grassi

Recorded by Kirkpatrick (1925) from El Kossaima in north-east Sinai. Saleh (1938) found it at Ain Gedeirat near El Kossaima.

The author collected its larvae from a slow flowing stream fed from Ain

Gedeirat with thick floatage of green algae over the surface of the clear water of the stream. These larvae were found in association with those of *Anopheles dthali*, *Anopheles turkhudi*, *Anopheles sergenti* and *Culex sinaiticus* (see Table I).

Distribution : Egypt (Kirkpatrick, 1925, and Storey, 1918), Syria and Lebanon (Leeson, 1950), Transjordan (Lumsden, 1950), Palestine (Shapiro, 1944), Iraq and North Persia (Macan, 1950), and Arabia (Buxton, 1944).

***Anopheles (Myzomyia) multicolor* Camb.**

Kirkpatrick (1925) reported this species from El Kossaima and El Moweilleh in north-east Sinai. Salem (1938) found it near El Arish and at El Moweilleh in Sinai.

The author collected larvae from three places in north-east Sinai : (1) at El Kherba in Rafah, 200 meters off the Mediterranean coast, from a borrow pit (tamila) 60 cm. deep with stagnant brackish water, in association with larvae of *Culex laticinctus*, *Culex sinaiticus* and *Culex theileri*; (2) at Bir Kharuba, 20 miles east of El Arish, from a borrow pit 50 cm. deep with stagnant brackish turbid water having green algae floatage, in association with larvae of *Culex theileri*; (3) at Abou Sagal in Wadi El Arish, 200 meters off the Mediterranean coast, also in a stagnant borrow pit 50 cm. deep with clear water.

Distribution : Egypt, Syria and Lebanon, Transjordan, Palestine, Iraq and North Persia, and Arabia.

***Anopheles (Myzomyia) dthali* Patton**

Previously recorded from Sinai under the name *Anopheles rhodesiensis* by Kirkpatrick (1925) who found it in south-east of El Arish, at Moweilleh, Kossaima and Ain Gedeirat. Salem (1938) failed to find it in north Sinai but collected it in southern Sinai at El Tor and at the Arbiceen near the Monastery of Sinai. Samples were captured by the author at Ain Gedeirat from a weedy pool 15 cm. deep with slow moving clear water and green algae floatage. The larvae were found in association with those of *Anopheles superpictus*, *Anopheles turkhudi*, *Anopheles sergenti* and *Culex sinaiticus* (see Table I).

Distribution : Egypt, Transjordan, Iraq, North Persia, Arabia, and Yemen (Knight, 1953).

***Anopheles (Myzomyia) turkhudi* Liston**

Salem (1938) collected its larvae from Ain Gedeirat near the Egyptian frontier to Palestine as well as from small collections of water near the summit of a mountain on the side of the mountain of Sinai. That was the only record

from Sinai. The author collected larvae at Ain Gedeirat from a weedy pool 15 cm. deep with slow moving clear water and green algae floatage. They were found in association with larvae of *Anopheles superpictus*, *Anopheles dthali*, *Anopheles sergenti* and *Culex sinaiticus* (see Table I).

Distribution : Egypt, North Persia, Arabia and Yemen.

***Anopheles (Myzomyia) sergenti* Theo.**

Found by Kirkpatrick (1925) at Ain Mousa in Sinai. Salem (1938) collected its larvae from Ain Gedeirat and Ain Kadeis in north Sinai.

Larvae were obtained by the author at Ain Gedeirat from a weedy pool 15 cm. deep with slow moving clear water and green algae floatage. They were found in association with larvae of *Anopheles superpictus*, *Anopheles dthali*, *Anopheles turkhudi* and *Culex sinaiticus* (see Table I).

Distribution: Egypt (Kirkpatrick, 1925), Syria and Lebanon (Leeson, 1950), Transjordan (Lumsden, 1950), Palestine (Shapiro, 1944), Arabia (Buxton, 1944, and Leeson, 1948), Bahrein (Afridi and Majid, 1938), and Yemen (Knight, 1953).

***Culex (Culex) laticinctus* Edw.**

Recorded by Kirkpatrick (1925) from Ain Kadeis in Sinai. Salem (1938) reported it from north and south parts of Sinai.

The author collected larvae from different places in north-eastern Sinai. They were found in El Kherba near Rafah breeding in a borrow pit (tamila) 60 cm. deep with brackish stagnant turbid water, in association with larvae of *Anopheles multicolor*, *Culex sinaiticus* and *Culex theileri*. Larvae were also found in El Arish in a disused shallow well in the middle of a palm tree garden. In this site, they were in association with larvae of *Culex pipiens* and *Culex univittatus* (see Table I). Larvae were also found alone in Abou Sagal near Nabi Yasir in El Arish, breeding in an unused artificial tank containing brackish water used for watering a palm tree garden.

Distribution: Egypt (Kirkpatrick, 1925), Syria and Lebanon (Parr, 1943). Knight (1953) reported it from Yemen.

***Culex (Culex) sinaiticus* Kirkpatrick**

Kirkpatrick (1925) has recorded this species from the Peninsula of Sinai in El Kossaima, El Mowcilleh, Ain Gedeirat and Ain Kadeis, near the Palestine frontier about 60 to 70 miles south-east of El Arish, and at Ain Mousa south-east of Suez. Also recorded by Salem (1938) from north and south parts of Sinai.

The author found the larvae breeding in various sites in different places

in north-eastern Sinai. In El Kherba near Rafah, the larvae were collected from a borrow pit (tamila) 60 cm. deep having stagnant brackish moderately polluted water, in association with larvae of *Anopheles multicolor*, *Culex laticinctus* and *Culex theileri*. Larvae were found near Bir Kharuba 20 miles east of El Arish in a fresh water pool with stagnant water and green algae floatage. In this site, they were in association with larvae of *Culex theileri* and *Culex univittatus*. At Wadi Gedeirat, the larvae were collected from a small slow-moving stream of fresh water, running over grass on the road 10 kilometers from the rest house, in association with larvae of *Anopheles superpictus*. At Ain Gedeirat, larvae were obtained from a slow-flowing stream fed from the Ain with thick floatage of green algae over the surface of the clear fresh water, in association with larvae of *Anopheles turkhudi*, *Anopheles sergenti*, *Anopheles dthali* and *Anopheles superpictus* (see Table I).

This species is not at present recorded from any other part of the Middle East except Sinai, Egypt, and Yemen (K n i g h t, 1953).

***Culex (Culex) theileri* Theobald**

Recorded by Kirkpatrick (1925) as *Culex tipuliformis* Theo. from El Arish in Sinai. Salem (1938) collected examples during August and September from north and south Sinai.

Larvae were collected by the author at El Kherba in Rafah 200 meters off the Mediterranean coast, from a shallow borrow pit 60 cm. deep with moderately-foul stagnant brackish water with no vegetation. In this site they were in association with larvae of *Anopheles multicolor*, *Culex laticinctus* and *Culex sinaiticus*. Larvae were also collected at Bir Kharuba 20 kilometres east of El Arish from a stagnant shallow pool 15 cm. deep with brackish water and green algae floatage, in association with larvae of *Anopheles multicolor*, *Culex sinaiticus* and *Culex univittatus* (see Table I)

Distribution: Egypt (Kirkpatrick, 1925), Syria and Lebanon (Parr, 1943), Iraq (Khattat, 1955), and Yemen (K n i g h t, 1953).

***Culex (Culex) univittatus* Theobald**

This species was recorded by Kirkpatrick (1925) from El Arish in Sinai under the name *Culex perexiguus* Theo.

The author collected the larvae from various sites at different places in north-east Sinai. In Rafah, larvae were encountered in a small shallow stagnant pool with emergent weeds and submerged algae, in association with larvae of *Culex pipiens*. At Bir Kharuba 20 kilometers east of El Arish, larvae were collected from a shallow borrow pit with stagnant clear water having no vegetation, in association with larvae of *Culex sinaiticus* and *Culex*

theileri. At El Arish behind Nabi Yasir where there are the vegetable gardens, the larvae were collected from a disused well, from a barrel containing foul water and from unused borrow pits containing moderately polluted water, in association with larvae of *Culex pipiens*, *Culex laticinctus*, *Aedes caspius* and *Uranotaenia unguiculata* (see Table I).

Distribution : Egypt and Yemen.

***Culex (Culex) pipiens* Linnaeus**

Kirkpatrick has recorded this species from El Arish and Bir Fuwara east of Ismailia. Salem also recorded it from El Arish. The author found it at El Arish from a variety of different sites including unused stagnant borrow pits with much pollution, disused well in the midst of a palm grove, a barrel containing foul water. In practically all these sites, the larvae were in association with larvae of *Culex univittatus*, *Culex laticinctus*, *Aedes caspius* and *Uranotaenia unguiculata*. From Rafah, larvae of *Culex pipiens* were collected together with larvae of *Culex univittatus* from a stagnant small pool with emergent weeds and brown algae floatage (see Table I).

On examination of the *Culex pipiens* larvae collected from all the sites mentioned above in northeast Sinai, the author found that they were morphologically similar to *Culex pipiens* larvae from Cairo (Knight and Abdel-Malek, 1951). The only difference was found to be in the "siphon index average", being 3.8 in Sinai *pipiens* and 3.7 in Cairo *pipiens*.

Distribution : Egypt, Syria, Lebanon, Iraq and Yemen.

***Aedes (Ochlerotatus) caspius* Pallas**

This species was not reported from north Sinai before. The only record for Sinai is from Bir Fuwara east of Ismailia (Kirkpatrick, 1925).

The author collected the larvae at El Arish behind Nabi Yasir in the vegetable gardens from an unused borrow pit with stagnant much polluted water, in association with larvae of *Culex pipiens*, *Culex univittatus* and *Uranotaenia unguiculata* (see Table I).

Distribution : Egypt (Kirkpatrick, 1925), Iraq (Khattat, 1955), and Iran (Ghaffary, 1954),

***Uranotaenia unguiculata* Edw.**

A species unrecorded from Sinai before. The author collected the larvae at El Arish behind Nabi Yasir in the vegetable gardens shaded by palm trees, from an unused stagnant borrow pit with much polluted water, in association with larvae of *Aedes caspius*, *Culex pipiens* and *Culex univittatus* (see Table I).

Distribution : Egypt, Syria, Lebanon and Iraq.

TABLE I

The association with each other of the larvae of different species
of north-eastern Sinai

SPECIES	<i>An. superpictus</i>	<i>An. multicolor</i>	<i>An. dhali</i>	<i>An. turkhudi</i>	<i>An. sergenti</i>	<i>C. laticinctus</i>	<i>C. sinaiticus</i>	<i>C. theileri</i>	<i>C. unioittatus</i>	<i>C. pipiens</i>	<i>A. caspius</i>	<i>U. unguiculata</i>
<i>An. superpictus</i>			2	2	1		3					
<i>An. multicolor</i>		(1)				1	1	2				
<i>An. dhali</i>	2			3	1		2					
<i>An. turkhudi</i>	2		3		1		2					
<i>An. sergenti</i>	1		1	1			1					
<i>C. laticinctus</i>		1				(1)	1	1	1	1		
<i>C. sinaiticus</i>	3	1	2	2	1	1		2	2			
<i>C. theileri</i>		2				1	2		1			
<i>C. unioittatus</i>						1	2	1		6	1	1
<i>C. pipiens</i>						1			6		1	1
<i>A. caspius</i>									1	1		1
<i>U. unguiculata</i>									1	1	1	

The figures in parentheses denote the number of times each species occurred alone.

In addition to the five anopheline species collected by the author from north-east Sinai, Salem (1938) recorded *Anopheles rupicolus* Lewis from southern Sinai. Salem also recorded *Anopheles pharoensis* Theobald from El Arish, and Kirkpatrick (1925) recorded the same species from Bir Fuwara (east of Ismailia), and Ain Moussa (near Suez). So there exist seven anopheline species so far recorded from Sinai.

The following is a simple key for the identification of the anopheline larvae recorded from Sinai. This key has been adapted from Evans (1938) and Leeson (1948).

KEY TO THE ANOPHELINE LARVAE RECORDED FROM SINAI

1. Inner clypeal hairs with bases nearly touching..... (**Anopheles**)
— Inner clypeal hairs with bases well separated(**Myzomyia**) 2
2. Outer clypeal hairs branched.....**pharoensis**
— Outer clypeal hairs simple or merely frayed.....3
3. Both long mesopleural bristles feathered.....**turkhudi**
— At least one of the long mesopleural bristles simple4
4. One long mesopleural bristle simple, the other feathered.....5
— Both long mesopleural bristles simple.....**dthali**
5. Both long metapleural bristles feathered.....6
— One long metapleural bristle simple, the other feathered7
6. Inner clypeal hairs showing a slight lateral fraying under high magnification, no spots around bases of frontal hairs**superpictus**
— Inner clypeal hairs completely unbranched, spots present around the bases of the frontal hairs**multicolor**
7. Head marked with a transverse band behind bases of frontal hairs; abdominal segments with 3 accessory tergal plates present; antennal shaft hair inserted at 0.15-0.35 length from base.....**sergenti**
— Head not marked with a transverse band behind bases of frontal hairs; abdominal segments with only 1 accessory tergal plate; antennal shaft hair inserted at 0.30-0.45 length from base**rupicolus**

With the addition of *Culex arbieeni* Salem, collected by Salem (1938 and 1940) from southern Sinai; also *Culex pusillus* Macq. and *Culex laurenti* Newst. recorded by the same author from north and south parts of Sinai; also *Culex quasigelidus* Theo. and *Theobaldia longiareolata* Macq. recorded by Kirkpatrick (1925), to the Culicine species recorded by the author in the present paper, there will be twelve Culicine species so far known from Sinai.

The following is a simple key for the identification of the larvae of the Culicine species recorded from Sinai. This key has been adapted from Kirkpatrick (1925), Parr (1943), Salem (1938), and Hopkins (1936).

KEY TO THE CULICINE LARVAE RECORDED FROM SINAI

1. Siphon with one pair of ventral tufts.....2
— Siphon with several tufts4
2. Siphonal tuft at the base; siphon with 6-10 widely-spaced pecten teeth **Theobaldia longiareolata**
— Siphonal tuft near the middle3

3. A large siphonal plate on each side of the abdominal segment VIII at the apex of which is a comb of spines in a single row **Uranotaenia unguiculata**
 — No chitinous plate on abdominal segment VIII, a patch of scales only; siphon about 2.5 times as large as broad; 3 hair tufts outside barred area of ventral brush **Aedes caspius**
4. Siphonal tufts in a single or slightly zigzag mid-ventral row 5
 — Siphonal tufts more or less paired 7
5. First 2 or 3 tufts between the pecten teeth 6
 — None of the tufts between the pecten teeth **Culex theileri**
6. Siphon about 3 times as long as broad, siphonal tufts in a simple regular row; small species **Culex pusillus**
 — Siphon at least 4 times as long as broad; siphonal tufts slightly zigzag; large species **Culex laticinctus**
7. Comb of the eighth abdominal segment with 7 or 8 teeth in a single row **Culex quasigelidus**
 — Comb of the eighth abdominal segment a patch of numerous small scales 8
8. Siphonal tufts in two sub-ventral rows 9
 — Siphonal tufts possessing sub-ventral, sub-dorsal and lateral hair tufts ...
 **Culex arbieeni**
9. Siphon not more than five times as long as broad; the inner post-antennal hairs with 5-6 branches **Culex pipiens**
 — Siphon at least five and half times as long as broad, generally more; the inner post-antennal hairs with at most 4 branches 10
10. Siphonal tufts very short, not more than half the diameter of the siphon (measured at the point of insertion of the tufts) **Culex laurenti**
 — Same tufts at least as long as the diameter of the siphon 11
11. Pecten teeth with eight to ten denticles; mid post-antennal hairs single or double, the inner pair single **Culex sinaiticus**
 — Pecten teeth with fewer denticles; mid post-antennal hairs double, the inner pair triple. Siphon with two pairs of small lateral tufts
 **Culex univittatus**

SUMMARY

A collection of mosquito larvae made in August 1951 in north-eastern Sinai is the basis for this paper. Biological and distributional notes are given for the twelve species collected. Two species new to this region were encountered, namely, *Uranotaenia unguiculata* Edwards and *Aedes (Ochlerotatus) caspius* Pallas. Simple keys for the identification of the Anopheline and Culicine larvae so far recorded from Sinai are devised.

REFERENCES

- Afridi, M. K., and Majid S. A. (1938): Malaria in Bahrein Islands (Persian Gulf) (*Jour. Mal. Inst. India*, I, pp. 427-472).
- Buxton, P. A. (1944): Rough notes: *Anopheles* mosquitoes and malaria in Arabia (*Trans. Roy. Soc. Trop. Med. Hyg.*, XXXVIII, pp. 204-214).
- Evans, A. M. (1938): Mosquitoes of the Ethiopian Region. II. Anopheline adults and early stages (British Museum [Natural History], London, 404 pp.).
- Ghaffary, E. N. (1954): Preliminary key to the fourth instar larvae of *Aedes* species occurring in Iran (Institute of Malariology Tehran (Personal communication)).
- Hopkins, G. H. E. (1936): Mosquitoes of the Ethiopian Region. I. Larval bionomics of mosquitoes and taxonomy of Culicine larvae (British Museum [Natural History], London, 250 pp.).
- Khattat, F. H. (1955): An account of the taxonomy and biology of the larvae of Culicine mosquitoes in Iraq [I. Central Iraq]. (*Bull. Ent. Dis.*, I, pp. 156-183).
- Kirkpatrick, T. W. (1925): The mosquitoes of Egypt (Egyptian Government Press, Cairo, 224 pp., 24 plates).
- Knight, K. L. (1953): The mosquitoes of the Yemen (*Ent. Soc. Wash.*, LV (5), pp. 212-234).
- Knight, K. L., and Abdel-Malek, A. A. (1951): A morphological and biological study of *Culex pipiens* in the Cairo Area of Egypt (*Bull. Soc. Fouad 1er. Entom.*, XXXV, pp. 175-185).
- Leeson, H. S. (1948): Anopheline larvae collected in Arabia (*Ann. Trop. Med. Parasit.*, XLII, pp. 253-255).
- Leeson, H. S. (1950): Anopheline surveys in Syria and Lebanon, 1941 to 1943 [In *Anopheles* and Malaria in the Near East] (*Lond. Sch. Hyg. Trop. Med.*, Memoir 7, pp. 1-43).
- Lumsden, W. H. R. (1950): Anophelism and malaria in Transjordan and in the neighbouring parts of Palestine and Syria [In *Anopheles* and Malaria in the Near East] (*Lond. Sch. Hyg. Trop. Med.*, Memoir 7, pp. 47-108).
- Macan, T. T. (1950): The Anopheline mosquitoes of Iraq and North Persia [In *Anopheles* and Malaria in the Near East] (*Lond. Sch. Hyg. Trop. Med.*, Memoir 7, pp. 109-219).
- Parr, H. C. M. (1943): The Culicine mosquitoes of Syria and the Lebanon (*Bull. Ent. Res.*, XXXIV, pp. 245-251).
- Salem, H. H. (1938): The mosquito fauna of Sinai Peninsula (Egypt), with a description of two new species (Egyptian University, Faculty of Medicine, Pub. No. 16, Cairo).

- Sale m, H. H. (1940) : Further observations on *Anopheles rupicolus* Lewis, *Culex arbieeni* Salem and *Culex theileri* Theobald (*Bull. Soc. Fouad 1er Entom.*, XIV, pp. 11-16).
- Shapiro, J. M., Saliternik, Z., and Belferman, S. (1944): Malaria survey of the Dead Sea Area during 1942, including the description of a mosquito flight test and its results (*Trans. Roy. Soc. Trop. Med. Hyg.*, XXXVIII (2), pp. 95-116).
- Storey, G. (1918) : Keys for the determination of Egyptian mosquitoes and their larvae (*Bull. Soc. Ent. Egypte*, V, pp. 84-105).
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Notes on *Simuliidae* in the Sudan

[Diptera]

R

(with 2 Text - Figures)

Y. b.

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The known distribution of *Simuliidae* in the Sudan was recorded by Lewis (1953), and a semi-popular account of the two man-biting species was given by Lewis (1955). The present paper reports some additional observations including a collection from Jebel Marra which is an isolated mountain massif in the western Sudan.

Owing to changes in synonymy proposed by Freeman and De Meillon (1953), the Sudan list of *Simuliidae* now comprises 21 species and two "forms", and there have been several changes in name and status. *S. alcocki* var. *henrardi* Gibbins is synonymous with *S. alcocki*, *S. rotundum* Gibbins becomes *S. unicornutum* form *rotundum*, *S. nigratarsis* Coquillett (of the Sudan) becomes *S. aureosimile* Pomeroy, the formerly undescribed variation of *S. griseicollis* is *S. griseicollis* form *bifila* Freeman and De Meillon, *S. elgonense* Gibbins becomes *S. medusaeforme* var. *hargreavesi* Gibbins, and *S. lepidum* De Meillon becomes *S. vorax* Pomeroy.

NOTES ON SOME OF THE SPECIES

Simulium alcocki Pomeroy

The record from Kelling is incorrect.

Simulium ruficorne Macquart

New records are from Abdullah Beshir, Daia, Ein Fara (284 pupae collected), Kanunbuna, Jebel Komi, Kronga (in a small rivulet), Wadi Sirro, So'unga and Suni. At Ein Fara (Fig. 1) a spring in a hill gives rise to a permanent stream in semi-desert country.

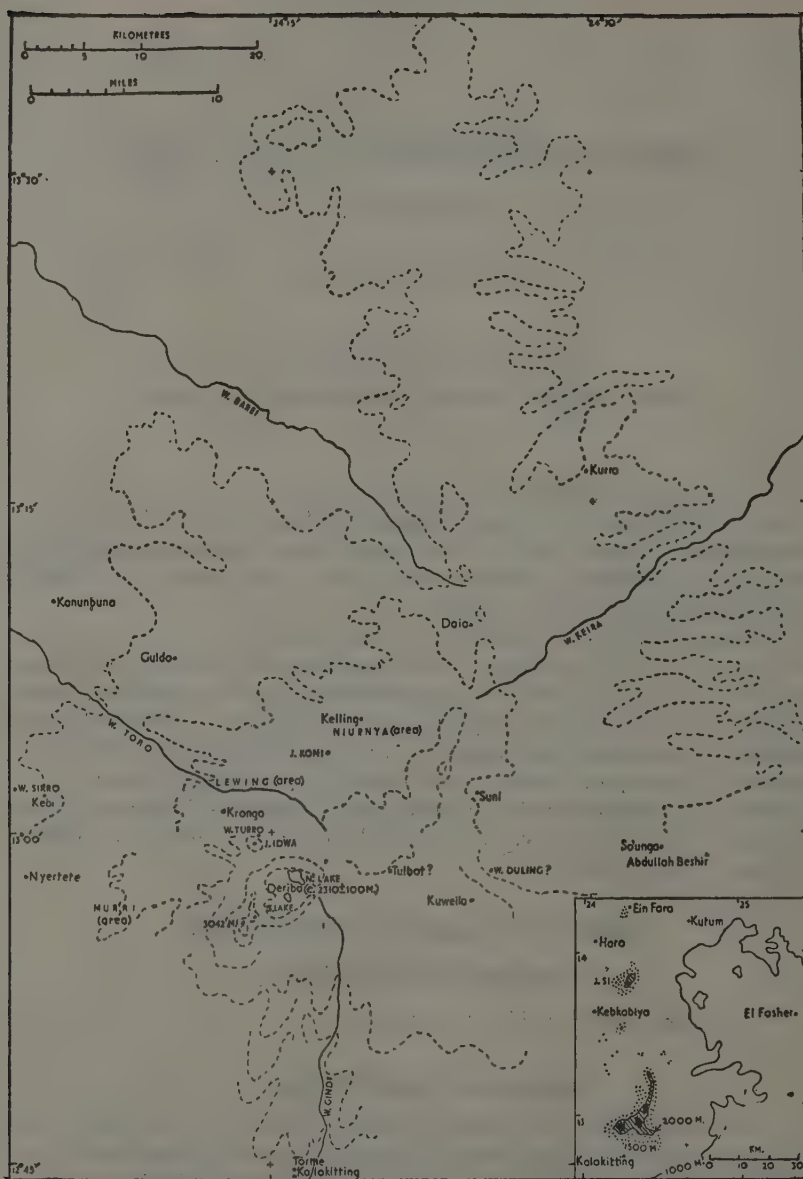


Fig. 1 : Showing some places on Jebel Marra including those mentioned in the text.

Simulium adersi Pomeroy

A few pupae of *S. adersi* and *S. damnosum*, and many of *S. griseicollae*, are often found in the Blue Nile at Wad Medani, the most northerly known locality of *S. adersi*, between December and March.

Simulium aureosimile Pomeroy

New records are from Wadi Duling, Kalokitting, Kelling (in weedy part of stream), Kuweila (P.D.), Suni and Tulbot (P.D.).

Simulium griseicollae Becker

Pupae at Khartoum are larger, and have a more strongly developed cocoon, than in other parts of Africa (Freeman and De Meillon, 1953).

NOTES ON THE LARVAE AND PUPAE

In the Fola Rapids, where there is a remarkable scarcity of simuliids, many of the rocks are thickly covered with green filamentous algae (Lewis, 1952) which may perhaps make the rocks unsuitable for *Simulium* larvae. Barnley (1953) found that algae increased on rocks and vegetation in the Nile near Jinja in Uganda after the use of DDT. He regarded this as an important factor in the control of *S. damnosum* and considered that it was due to the destruction of simuliid larvae which had previously fed on the algal spores. Another observation on algae was made at Wad Madani in the Sudan, where the weather was unusually cool in December 1953 with an average daily temperature range of 7.7 to 29.4°C. from the 11th to 20th. On 21st the writer examined some sedge in the Blue Nile, where many larvae and pupae of *griseicollae* are usually found, to see if the females had stopped laying eggs. The water temperature in the afternoon was 18.2°C. Many empty cocoons of *S. griseicollae* and a few of *S. adersi* and *S. damnosum* were found, together with a few pupae and a very few larvae of *S. griseicollae*. Pupal gills, cocoons and leaves were smothered in a tangled brown mass of various filamentous and other algae and miscellaneous debris. It may be that *Simulium* larvae browse on the algae which flourish when the larvae are scarce and many delay their re-establishment.

Young larvae of *S. griseicollae*, presumably supported by threads as described by Bequaert (1934), have been found drifting in the Blue Nile at Khartoum in the evening when tow-nets were being used to collect chironomid pupae. The river is several metres deep at this point and contains no rocks and scarcely any aquatic vegetation. It flows very slowly at this season, only about 700 metres per hour at the surface, and a little faster at

places upstream. Up to six larvae, in January, and 14 in February, in two instars, were taken in half-hour catches made with tow-nets 30 cm. in diameter. These larvae probably represented a drift of many thousands per hour past Khartoum. Pupae of *S. griseicollis* occur in slowly moving water in Dongola, as well as in rapids, and the species can evidently tolerate great differences in speed of water.

Pupae at Wad Madani tend to occur among the inflorescence and surrounding leaves of sedge which protect them from predators. Separate leaves were pinned on cork sheets in a mosquito-wire cage in the river in preparation for some observations on the time of emergence. When the cage was removed from the strips the pupae and cocoons soon disappeared.

Among possible methods of control the oiling of breeding places to kill emerging adults was considered, and observations were accordingly made to ascertain the time of emergence. When pupae were kept in running water in the laboratory many died, so the work was transferred to the breeding place (the Blue Nile at Wad Medani), in December, when the water temperature varied from 23 to 25°C. Bunches of sedge with pupae were placed in a cylinder of chicken wire which was put in the narrow end of a tow-net anchored in fast-flowing water, and a cloth bag was attached to the trailing end of the net to catch emerging adults. The bag was later removed and put in formalin, and was replaced by others at intervals. Preliminary observations lasting three days indicated that most adults emerged by day, that there was no peak of emergence at dawn or dusk, and that more than three quarters of the adults emerged during the day before 13.30 hours. Two 24-hour catches made at intervals of about three hours (quarters of the day and night) showed (Fig. 2) that the emergence period was protracted and that most flies emerged in the morning and a considerable number after mid-day. A few hourly catches gave rather similar results. Of the 298 flies obtained in the 24-hour catches 88 per cent emerged during the day. The males and females emerged about the same time in almost exact equal numbers, 49.45 per cent of 839 flies being males. The emergence time of *S. griseicollis* is rather like that of Canadian species which emerge throughout the daylight hours but not usually at night (Sprules, 1947).

NOTES ON THE ADULTS

The Malpighian tubes of *S. griseicollis*, unlike those of *S. damnosum*, often have a pink tinge, and the ovaries develop in individuals which have fed on raisins but not sucked blood. In this respect *S. griseicollis* resembles many Canadian species which in nature apparently lay eggs without having had a meal of blood (Hocking and Pickering, 1954).

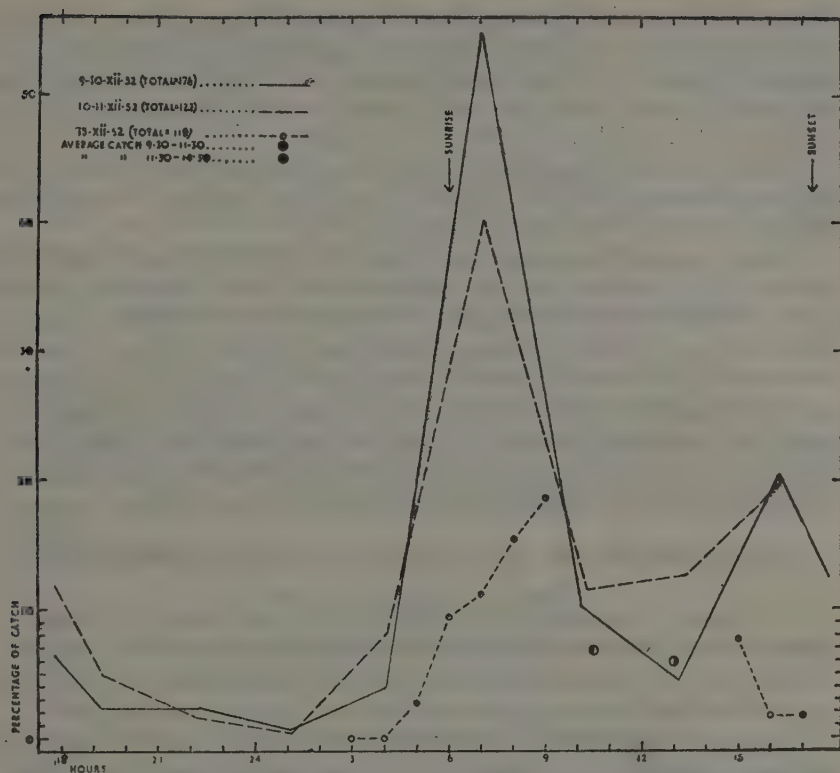


Fig. 2 : The emergence times of *Simulium griseicollae* as shown by collections of adults in a tow-net, stocked with pupae, in the Blue Nile at Wad Medani. Each point is at the centre of a collecting period.

With regard to the range of flight, or carriage by the wind, of this species, Lewis (1948) referred to a record by Edwards and others of a 200-mile flight about which no details are available. It seems not unlikely that this record was based on the finding, by Mr. W. Ruttledge, of *S. griseicollae* around caged pigeons at Umm Inderaba on 5th January 1929. This place is separated by 325 kilometres (about 200 miles) of bare wind-swept country from Debba which lies roughly north-north-west of it at the southern end of the main *S. griseicollae* area. Meteorological records taken twice a day at Khartoum, however, show that during the preceding four days the wind varied from north to north-east with speeds up to 12 km. per hour. This being so, it is probable that the flies had come from a reach of the Nile below Khartoum over 100 km. (60 miles) away from Umm Inderaba.

During studies on *S. damnosum* at Mvolo in the southern Sudan hundreds

of pupae of *S. griseicollae* were collected but no adults were seen. A single female was found on a boy at Lubu, but it appears that the species rarely, if ever, bites man in the onchocerciasis areas. The fact that it bites in the north may be due to attacks by a small proportion of the vast numbers present rather than to any inherent difference in behaviour.

When the Blue Nile at Khartoum was covered with oil at dusk to kill chironomids many adults of *S. griseicollae* were found trapped by the oil but it is not known how they came to be there.

Some females of this species were dissected at Wad Medani and the hind intestine of one was found to contain a fungus of the genus *Cladosporium*, several species of which are known to occur by chance in the intestines of insects (Steinhaus, 1947). I am informed by Dr. S.A.J. Tarr that in the Sudan a *Cladosporium* often occurs on honey-dew which is excreted in large quantities by White Flies (*Aleyrodidae*). When simuliids are abundant it would be interesting to notice if they feed on honey-dew which might conceivably be the source of some of the dust particles and sugar which are found in the crop of *S. damnosum* in the Sudan (Lewis, 1952).

THE PROBLEM OF *S. GRISEICOLLE* IN DONGOLA

The annual outbreaks of "nimitti", as this species is called in Dongola, usually occur in February and March but the period and severity are variable. In one year nimitti were reported to have been troublesome for the first three weeks of February, and in another year to have lasted till April.

Although *S. griseicollae* is a serious pest in Dongola its season is short and sometimes negligible, it transmits no disease, and measures to protect individual men and animals have some effect. There is little or no prospect of controlling *S. griseicollae* in this rural area, remote from railways and proper roads. The Nile flows through it for over 300 km., slowly in most places and with an average discharge of more than eighty million cubic metres a day during February, and there is no convenient narrow channel upstream for the application of insecticide. The use of larvicides or of any other known method of control would be extremely expensive.

A film of oil on the water would kill emerging adults but would have to be applied for many hours each day (Fig. 2) and the treated area would be invaded by nimitti from downstream since the river flows from south to north and the prevailing wind is northerly.

With regard to personal protection, reports from Dongola indicate that neither dimethyl phthalate nor Citronella oil prevent the adults from setting on the skin, but that the former stops them biting. Annoyance is mainly due to nimitti settling and crawling on the face, which can be prevented by the use of veils of material with a mesh of 0.8 mm. Impregnating coarser material

(8 mm.) with dimethyl phthalate is ineffective. Goggles are of little use unless an olfactory repellent can be found to protect the rest of the face.

Cattle and horses can be protected by smoke fires or darkened shelters, and can graze at night.

***Simulium dentulosum* Roubaud**

New records are from Wadi Duling (P.D.), J. Komi, Kronga, Suni and Torme (at top of waterfall above village).

***Simulium medusaeforme* var. *hargreavesi* Gibbins**

The respiratory organs of pupae from the Sudan are figured by Freeman and De Meillon (1953).

New records are from Abdullah Beshir (near lower end of stream; larvae, but scarcely any pupae found), Wadi Duling (P.D.), Ein Fara (232 pupae collected), Guldo (few), Kalokitting, Kanunbuna, Kelling, J. Komi, Kronga, Nyertete, Wadi Sirro, So'unga Suni, Torme (above waterfall) and Tulbot (P.D.).

***Simulium arnoldi* Gibbins**

The distribution of this species in the Sudan and elsewhere is discussed by Freeman and De Meillon (1953).

***Simulium damnosum* Theobald**

Grenier and Ovazza (1951) found that in some larvae from the Sudan there is little pigment in the fronto-clypeus and that there are dark and well-developed tubercles on the abdomen.

This species has been found by Mr. E.T.M. Reid biting a buffalo which he had shot about two km. from the R. Pongo and six km. north-west of Bahr Mayon Dit which is 8° 21' N. and 27° 37' E. Several of the same species bit Mr. Reid at a place nearby where the buffalo had been resting.

Since Lewis (1952) discussed the control of *S. damnosum* in the onchocerciasis area the enhanced value of DDT in certain fast-flowing turbid rivers has been discovered (Fredeen and others 1953; World Health Organization, 1954). It might be worth while to attempt control along one of the southern rivers if it is economically feasible. In view of practical difficulties, however, the systematic removal of *Onchocerca* nodules (W.H.O., 1954) for reducing blindness might also be considered.

The construction of the proposed dam at the Damasin rapids near Roseires (Sudan Government, 1954) would involve the creation of a residential centre in a *S. damnosum* area not very far from a district where onchocerciasis

is suspected to exist. There may, however, be no risk either of serious annoyance or of infection. The proposed site, like that of the Sennar dam, is on a rock outcrop where *Simulium* breeds. *S. damnosum* is not known to be particularly annoying at Damasin and it will presumably cease to breed for some distance above the dam. Breeding may continue below the dam and larvae may appear, as at Sennar, in narrow channels of seepage water at the foot of the downstream face.

THE SIMULIIDAE OF JEBEL MARRA

The shape of J. Marra is roughly indicated by form lines (selected from those in the 1:250,000 Sudan Government Survey Department map) because an accurate contour survey has not been made. Many permanent streams descend the slopes of the massif but in the dry season none of them continues more than a short way into the surrounding plain which is entirely devoid of surface water at this time. The simuliids of J. Marra have probably been isolated for a long period. The mountain streams are strewn with boulders and water-plants grow in several places. Records mentioned in previous papers were derived from two collections. In October, 1947 many pupae of *S. aureosimile* and *S. dentulosum* and some of *S. medusaeforme* var. *hargreavesi* were found at Suni and in the So'unga-Abdullah Beshir area (formerly recorded as Tangal) in the same valley, and in April 1950 a few specimens of *S. alcocki* and *S. ruficorne* were taken at Kalokitting.

The writer visited the mountain in January 1954, travelling from El Fasher to Suni, Kalokitting, Zalingei, Nyertete and Kronga by road, to Deriba, Kelling and Guldo by mule, and to Kutum and Ein Fara by road. Pupae collected numbered 1873, comprising 192 *S. ruficorne*, 91 *S. aureosimile*, 34 *S. dentulosum* and 1556 *S. medusaeforme* var. *hargreavesi*. The striking features of the collection were the small number of species and the large numbers of *S. m.* var. *hargreavesi* whose larvae blackened the rocks in many places. Sixteen Sudan species are apparently absent and they fortunately include *S. griseicollae* and *S. damnosum* for which special search was made in the lower reaches. No simuliids were seen to bite man, and it seems certain that *S. m.* var. *hargreavesi* does not do so.

SUMMARY

This paper records various observations including the results of a survey of Jebel Marra where few species occur but *S. medusaeforme* var. *hargreavesi* is abundant. Observations on the emergence time and other features of *S. griseicollae* Becker are recorded.

ACKNOWLEDGMENTS

I am much indebted to Sayed Ali Abdullah Abu Sin, Dr. Khalil Abd er Rahman and Osman Eff. Mohamed Kheir for help in arrangement to visit Jebel Marra; Mr. P. Durran and Mr. E.T.M. Reid for contributing specimens as indicated in the text; Mr. G. R. Barnley for information about *Simulium* larvae near Jinja; the Sudan Government Meteorologist for wind data; and Dr. G.A. Prowse and Dr. S.A.J. Tarr for information about algae and fungi.

REFERENCES

- Barnley, G. R. (1953) : The control of *Simulium damnosum* Theobald on the Victoria Nile, Uganda (W. H. O. supporting document, Onchocerciasis, 18. Duplicated).
- Bequaert, J.C. (1934) : Notes on the black-flies or *Simuliidae* (R.P. Strong and others. Onchocerciasis.....pp. 175-224, Cambridge, Harvard Univ. Press).
- Fredeen, F.J.H., Arnason, A.P., and Berck, B. (1953) : Adsorption of DDT on suspended solids in river water and its role in black-fly control (*Nature*, CLXXI, p. 700).
- Freeman, P., and De Meillon, B. (1953) : Simuliidae of the Ethiopian Region (London, British Museum (Nat. Hist.)).
- Grenier, P., and Ovazza, M. (1951) : Simulides du Moyen Congo (*Bull. Soc. Path. exot.*, XLIV, pp. 222-234).
- Hocking, B., and Pickering, L.R. (1954) : Observations on the bionomics of some northern species of *Simuliidae* (Diptera) (*Canadian J. Zool.*, XXXII, pp. 99-119).
- Lewis, D.J. (1948) : The Simuliidae of the Anglo-Egyptian Sudan (*Trans. R. ent. Soc. Lond.*, XLIX, pp. 475-496).
- Lewis, D.J. (1952) : *Simulium damnosum* and its relation to onchocerciasis in the Anglo-Egyptian Sudan (*Bull. ent. Res.*, XLIII, pp. 597-644).
- Lewis, D.J. (1953) : Simuliidae in the Anglo-Egyptian Sudan (*Rev. Zool. Bot. afr.*, XLVIII, 269-286).
- Lewis, D.J. (1955) : *Nimitti* and some other small annoying flies in the Sudan (In the press).
- Sprules, W.M. (1947) : Ecological investigations of stream insects in Algonquin Park, Ontario (Univ. Toronto Press, Biol. ser., no. 56).
- Steinhaus, E.A. (1947) : Insect microbiology (New-York, Comstock).
- Sudan Government (1954) : Roseires dam project report (By Sir Alexander Gibb & Partners, Unpublished).

World Health Organization (1954) : Expert Committee on onchocerciasis, first report (Tech. Rep. Ser., no. 87, Geneva).

The male *Eulecanium corni* Bouché

[Hemiptera-Homoptera : Coccoidea-Coccidae]

R

(with 5 Text - Figures)

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Apart from Green's remark (1930) in which he stated that he had frequently found the empty male puparia of *E. corni*, in association with the female scales, on a peach tree in his garden at Camberly, and that they were of the usual Lecaniid type, the male of this insect has not been previously recorded in England.

The description of the male of *E. corni* collected from Yew from a Nursery in Surrey, and given by Gimingham (1934) refers to that of *E. taxi* which was found by the present author to be a distinctly different species.

It is evident from the review of literature, that the males of this insect are very rare and have a sporadic occurrence. Marchal (1908) stated that he had only recorded them on one plant in France which is *Robinia pseudoacacia* and that bisexual reproduction is not common. Cusculanna (1933), when writing on *E. corni* as a pest of plum trees in Italy, gave a short description of the male with some illustrations. Thiem (1933) stated that no males have been recorded from England and Denmark, and that the proportions of sexes in this species are much affected by climatic conditions and altitude ; above 1600 feet no males have been recorded. He also indicated that the species maintained itself chiefly by parthenogenesis.

It may be interesting to state that amongst the twenty two different host plants harbouring *E. corni* and examined by the present author in Great Britain, the males were not found except on one plant, *Cotoneaster microphylla*, from the Royal Horticulture Society Gardens at Wisely. A comparatively fuller description of the male is given below, together with a brief account on its biology.

Note : The colours referred to were tested according to the Color Standards and Nomenclature, by Ridgway.

MORPHOLOGY

The two sexes cannot be separated in the first nymphal stage. In the second nymphal stage also, there are no definite morphological differences, except that the nymphs of the males are almost always narrower and longer than those of the females.

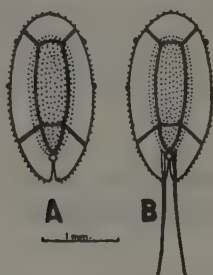


Fig. 1 : (A) The puparium of the male; (B) Protrusion of the caudal filaments before the emergence of the adult.

The puparium : The second stage nymph before changing to the prepupa, secretes a glassy white puparium (Fig. 1. A) under which it undergoes metamorphosis to the adult. The puparium appears at first opaque when covering the insect, but becomes very thin and transparent after the emergence of the adult male. It is oval, averages 2.2 mm. long, ranging from 2.1 to 2.3 mm., and 1.1 mm. wide, ranging from 1.0 to 1.2 mm. It is clearly divided by a more or less oval suture, parallel to the margin, into a central region and a marginal region. From this suture there arise on both sides two oblique sutures, anterior and posterior, which extend towards the margin, dividing the marginal region into five distinct plates. The central region is divided by a transverse suture into a long and broad anterior plate, and a small posterior plate, which tapers backwards and ends at the apex of the anal cleft. There are very minute setae all round the margin of the shell, and opposite the spiracles, a whitish secretion accumulates into four clear clusters.

The prepupa (Fig. 2, A) : This instar lasts for two or three days only and is easily overlooked. The wings, antennae and legs appear outside the body as minute protruberances. There is a very faint segmentation on both the antennae and legs. There are two pairs of spiracles below the lines of insertion of the coxae of the pro- and metathoracic legs. Abdominal segmentation is fairly clear and the abdomen ends with two lobes, one on either side of the genital organ which appears in this stage as a semi-globular protruberance. There are minute setae on the margin of the abdomen and of the abdominal lobes. The prepupa averages 1.8 mm. long, ranging from

1.7 to 1.9 mm., and 0.75 mm. wide, ranging from 0.7 to 0.8 mm.

The pupa (Fig. 2, B) : It is nearly of the same dimensions as the prepupa. The antennae, legs and wings grow much longer, and with clearer

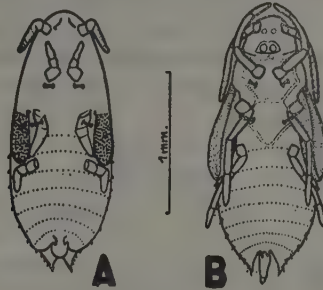


Fig. 2 : (A) Prepupa; (B) Pupa.

segmentation on both the legs and antennae. The wings appear to be folded inwards. Two pairs of ocelli appear on the head, a ventral pair on the posterior margin, and a smaller dorsal pair opposite the inner insertions of the antennae. The four spiracles are also present, and the thoracic skeleton starts appearing. The genital organ becomes longer and finger-like instead of being semi-globular. The marginal setae on the abdomen and abdominal lobes appear to grow from tubercular bases.

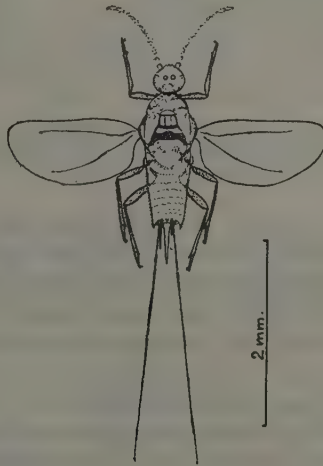


Fig. 3 : The adult male.

The adult male (Fig. 3) : It is of the ordinary *Lecaniid* type. The

colour of the body is Carnelian Red 7.R.O., while the head is rather blackish, and the antennae and legs are more or less yellowish. The wings are white and reflected light gives them a rosy appearance. It averages 2.5 mm. long, from the tip of the head to the end of the genital organ, ranging from 2.3 to 2.6 mm., and is 3.7 mm. wide, with the wings expanded, ranging from 3.5 to 3.9 mm. The head is more or less rounded, of about 0.33 mm. in diameter. It bears two pairs of ocelli, a ventral posterior pair of large ocelli, and a dorsal anterior pair of smaller ocelli.

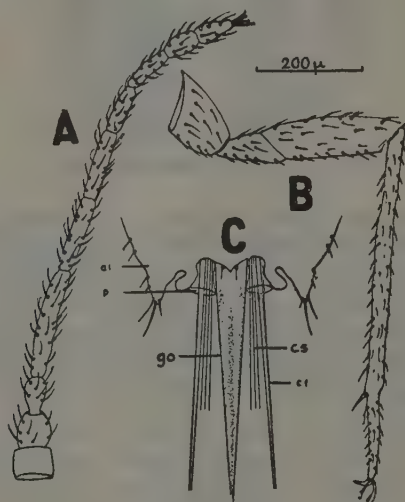


Fig. 4 : Various parts of the body of the adult male : (A) Antenna; (B) Metathoracic leg; (C) Posterior end of the abdomen (al., anal lobe ; cf., caudal filament ; cs., caudal setae ; go., genital organ ; p., pit).

The antennae (Fig. 4, A), is ten-segmented and measures 1 mm. long, ranging from 0.95 to 1.07 mm. The 4th. segment is the longest, the basal two broadest and shortest, and the 9th. and 10th. are slightly dilated. All segments are covered with dense finely pointed setae except the 10th. which besides that ends also with two pairs of capitate setae, the outer being slightly longer.

Mouth parts are completely absent.

The legs (Fig. 4, B) : are slender, and very nearly similar in length, except that the tibia of the prothoracic leg is slightly shorter. The average dimensions of the different parts of the metathoracic leg expressed in microns are : coxa, length 150, width 104; femur and trochanter, length 367, width 75; tibia, length 540, width 42; tarsus, length 165, width 33. All segments are

densely covered with setae, and the tibia ends internally with a comparatively long and stout tibial spur. The tibia of the prothoracic leg averages 494 μ long, and 42 μ wide.

The wings : The forewing is membrabous and measures 1.6 mm. long and 740 μ wide, with the usual two prominent veins. The hind wing is absent and is not even represented by a haltere.

The thorax is highly specialised. The prothorax (Fig. 5, A) has anteriorly a bent chitinised ridge on either side of its dorsal surface. It resembles an acrotergite and can be better termed as a protergal sclerite (pts.). Ventrally, there are two propleural sclerites (pps.) which extend on either side diverging posteriorly, and bending dorsally at their two extremities. They pass anteriorly below the protergal sclerite where they end with a secondary occipital articulation. Posteriorly they form, the coxal articulation. The rest of the prothorax is membranous. The mesothorax is comparatively large and is produced dorsally into a rounded hump. Dorsally (Fig. 5, B), the prescutum (psc.) ends anteriorly with an acrotergite (ac.). The scutum (sc.) has a heavily chitinised transverse band which counts for the previously considered dorsal hump. It ends posteriorly

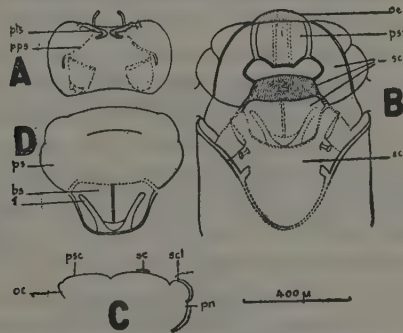


Fig. 5 : The thorax of the adult male : (A) Prothorax (dorsal) ; (B) Mesothorax (dorsal) ; (C) Diagram of the thorax from the side ; (D) Mesothorax (ventral) (ac., acrotergite ; bs., basisternum ; f., furca ; pn., postnotum ; pps., propleural sclerite ; ps., presternum ; psc., prescutum ; pts., protergal sclerite ; sc. scutum ; scl., scutellum).

with the scutellum (scl.) which slightly slopes downwards towards its hinder end where it meets the postnotum (pn.). The postnotum goes deep towards the ventral surface and is slightly bent forwards at its hinder extremity. Both the scutellum and the postnotum are overlapped by the metathorax as appears in the diagram of the side view (Fig. 5, C). Ventrally (Fig. 5, D) the presternum (ps.) occupies a relatively wider area than the basisternum (bs.). The furca (f.) arises from the posterior margin of the basisternum, with its

two arms diverging upwards. The metathorax is all membranous, and this may support the fact of the absence of the halteres. Four spiracles are present on the ventral surface of the thorax, opposite the lines of insertion of the coxae of the prothoracic and mesothoracic legs.

The abdomen is membranous, with faint segmentation. It ends posteriorly with the genital organ (Fig. 4, C : go) which is pointed from its hinder end and averages 470μ long. On either side of the genital organ there is an abdominal lobe (al.) which curves inwards, at its inner margin to form a sort of pit or invagination (p.). From each of these two pits comes out a band of setae and a very long waxy caudal filament (cf.) which averages 2.7 mm. long. The abdominal lobes end with three setae each, and marginal setae are also present on the abdominal segments.

A BRIEF ACCOUNT OF THE BIOLOGY

As previously considered the males of *E. corni* were observed on *Coton-easter microphylla*. Samples of infested twigs were repeatedly examined at the times when the puparia of the males were formed and the percentage of the males to the total population was found to be low. It was estimated as 4% ranging from 3 to 5%.

About the beginning of April the male second stage nymphs secrete a thin glassy text of wax, the puparium, under which they moult to the prepupae, pupae, and adults. The emergence of the adult males takes place about the end of April or early in May and is indicated about a day before by the protrusion of the waxy caudal filaments from the anal extremity of the puparium. The emergence of the adult usually takes place at mid-day, the insect lifting the puparium from its anal end and creeping out backwards. After a short period the male stretches its wings and flies. It has been observed both in the field and in the laboratory that the male mates with a single female. The male mounts the dorsum of the female in the same direction, inserts its aedeagus in the genital aperture through the anal cleft and raises the caudal filaments vertically upwards. The antennae then vibrate rapidly. This action lasts nearly 40 seconds and is repeated from 4 to 5 times alternating with a resting period lasting from 3 to 4 minutes. After copulation the male usually dies on the dorsum of the female. In very few cases the male moved after mating for about 3 cms., and died on the branch of the plant.

The males were easily reared in the laboratory by simply leaving the slivers of the bark with the puparia on them, in specimen tubes covered with muslin. The technique adopted for mating with the females was :

(a) In case of big trees, e.g. Peach, the specimen tube with the newly emerging male was put very near to one of the mature females. On removing the muslin cover, the male usually flew towards the female,

(b) In case of small potted plants, e.g. Blackberries, the pot was put under a celluloid cylinder, with a hole in its side wall. The specimen tube was opened and inserted in that hole, and the male could be watched from outside the cylinder.

From a series of transferring and mating experiments the following conclusions could be drawn.

- (1) The males could develop on host plants other than *Cotoneaster*.
- (2) Bisexual reproduction or in other words mated females gave rise to both males and females, but the percentage of males was always very low.
- (3) Parthenogenesis or unmated females gave rise to females only.
- (4) The failure of mating of males of *E. corni* with females of *E. taxi* and of the reciprocal mating, supports the morphological conclusion that *E. taxi* is a distinct species.

SUMMARY

The author records the male of *E. corni* for the first time in England on *Cotoneaster microphylla*, from the Royal Horticulture Society Gardens at Wisely. He gives a comparatively fuller account of its morphology with special reference to the highly specialised thorax of the adult, together with a brief account on its biology.

ACKNOWLEDGMENTS

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REFERENCES

- Cuscilanna, N. (1931) : La cocciniglia del Susiano, *Eulecanium corni* (Bouché), in Provincia di Trieste (*Boll. Lab. Zool. Portici*, XXIV, pp. 279-293).
- Gimingham, C. T. (1934) : The male *Lecanium corni* Bouché (*Ent. Mon. Mag.*, LXX, pp. 41-42).
- Gradojevic, M. (1933) : Sur la présence des mâles de la cochenille *Eulecanium corni* Bouché en Jugoslavia (Ext. Rec. Trav. J. Georgévitch Occas. 60th. Anniv., Belgrade, pp. 115-125, in Serbian with French summary).
- Green, E. E. (1930) : Observations on British Coccidae, XII, (*Ent. Mon. Mag.*, LXVI, pp. 9-17).
- Green, E. E. (1934) : Observations on British Coccidae, XIV (*Ent. Mon.*

- Mag.*, LXX, p. 108).
- M a r c h a l, P. (1908), : Note sur les Cocchenielles de l'Europe (*Annales Soc. Ent. France*, LXXVII, pp. 223-309).
- N e w s t e a d, R. (1900) : Monograph of the Coccidae of the British Isles.
- T h i e m, H. (1933) : Beitrag zur Parthenogenese und Phaenologie der Geschlechter von *Eulecanium corni* Bouché (Coccidae) (*Zeits. Morph. Oekol. Tiere*, XXVII, pp. 294-324, Berlin).
- T h o m s e n, M. (1928) : Sex determination in *Lecanium* (*Trans. 4th. Inter. Congr. Ent. Ithaca*, II, pp. 18-24).
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Studies on the biometrics of the Egyptian honeybee, *Apis mellifera fasciata* Latr.

L [Hymenoptera : Apoidea]

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INTRODUCTION

The Egyptian honeybee, *Apis mellifera fasciata* Latr., is the recognised descendent of the Pharaonic bee kept by ancient Egyptians, which appears on the Egyptian monuments as early as 3500 B.C.

No work, has been done on the morphology and the biology of the Egyptian bees, neither in their native hives, nor in movable frame hives.

The aim of this work is to offer sufficient studies on these subjects.

REVIEW OF LITERATURE

Workers who studied the biometry of the honeybee included in their investigations, the following important characters :

1. The length of the scapus which contains the sense factors.
2. The length of the tongue (proboscis), upon which depends the quantity of nectar gathered from flowers at different levels.
3. The size of the hind-legs, especially the first joint of the tarsus (basitarsus), which is the main organ in carrying pollen.
4. The size of the fore-wings, and the number of hooks on hind-wings, which have great influence on the flying ability when foraging.
5. The size of the surface of the wax glands, which secrete the wax used in comb-building and capping over the honey.

Алпатов (1929) found that the size of the body was correlated with the reduction of the larval feeding period. In many cases the changes in

in absolute dimensions of the bee body had been accompanied by changes in proportions of the body. He found also that the tongue length of the Black bee of Middle Russia (*Apis mellifera mellifera* L.) was 6.115 ± 0.003 mm., and the tongue length of the Black bee of U.S.A. (*Apis mellifera mellifera* L.) was 5.974 ± 0.007 mm. The tongue length of the Italian bee (*Apis mellifera ligustica* Sp.) was 6.234 ± 0.01 mm. when reared in Italy, 6.22 ± 0.0 when reared in Ithaca (New-York), and 6.419 ± 0.012 mm. when reared in Ohio, U.S.A. He found also that the tongue length of the Yellow Caucasian bee (*Apis mellifera remipes* Gerst.) reared in Migri, Armenia, was 6.511 ± 0.02 mm., and the tongue length of the Gray Caucasian bee from Mingrelia (*Apis mellifera caucasica* Gorb.) was 6.856 ± 0.01 mm.

Archivfur (1931) noted that long wings and tongues usually go together, and drew attention to the cubital index as a rough guide to tongue length.

Ruttner and Mackensen (1952) stated that these characteristics are the chief groups in racial studies :

1. Hair characteristics : (a) colour of hair; (b) length of the "over-hair" on the fifth tergite; (c) the tomentum index which is the ratio of the width of the tomentum (band of hairs in the middle of the abdominal tergite of the workers), to the width of the comparatively bare chitinous strip, between the tomentum and the posterior margin of the tergite, measured on the fourth tergite.

2. The cubital index (or wing index) which is defined as the ratio of the two parts of the lower vein of the third cubital cell, of the front wing.

3. Length of the proboscis.

They estimated these characteristics in the races of the central Europe, and found that the tongue length was 6.3 mm. in the race *mellifera*, 6.5 mm. in the race *ligustica*, and 6.7 mm. in the race *carstica*. The cubital index was 1.8, 2.3 and 2.7 respectively, and the tomentum index was 1.0, 2.3 and 2.7.

TECHNIQUE AND MATERIAL

In the present investigations, it was preferred to study the biometrics of the characters which have biological significance, according to their economic value to the honeybees and hence to the beekeepers. The technique used by Alpatov (1929) was adopted. The best method to ensure the fully extension of the proboscis is to kill the bees (slightly anaesthetized by means of the usual anaesthetics adopted in entomological practice: ether, calcium cyanide, etc.) by dropping them into boiling water. This method was used in carrying out all measurements of the different organs of the Egyptian bees. Dissected parts were measured in water. Glycerin jelly was used as a medium for preservation. These measurements were taken on Egyptian workers,

obtained from pipe-hives, and others from movable-frame hives with comb foundations.

Weights of workers newly emerging from natural brood combs, were recorded to be compared by workers newly emerging from Langstroth brood combs, reared by egyptian colonies of honeybees.

The weights of newly emerging drones, the dimensions of the forewings, the cubital index and the number of hooks on the hind wing, were also calculated.

Virgin queens were weighed after emerging and some of them were dissected to count the number of their ovarioles, which indicate the capacity of egg-laying.

RESULTS

Biometrical characteristics of workers

The results show that the Egyptian worker bee, which has newly emerged, weighs 69.88 ± 0.62 mgms., when reared in a comb built in a pipe-hive, and that this weight is increased when it is reared on comb foundation to 89.04 ± 1.15 mgms. The dimensions of different organs are increased also when bees are reared in Langstroth hives.

The flagellum (the longer part of the antenna) which contains a great number of the sense organs, is 2.76 ± 0.01 mm. in length when the bee is emerging from a natural comb, and 2.81 ± 0.006 mm. when emerging from a Langstroth comb.

The tongue length is 5.57 ± 0.02 mm. if the worker is reared in a natural comb, while it is 5.76 ± 0.01 mm. when reared in a Langstroth hive.

The basitarsus of the hind leg which is the main organ in carrying pollen from the flowers to the hive, is 1.92 ± 0.01 mm. in length and 1.06 ± 0.005 mm. in width when reared in a pipe-hive, and 2.03 ± 0.07 mm. in length and 1.14 ± 0.004 mm. in width when produced from the larger cells of the Langstroth hives.

The fore-wing of the worker is 8.14 ± 0.01 mm. in length, 2.76 ± 0.006 mm. in width, and it is attached to the hind-wing by an average of 20.48 ± 0.03 hooks, when reared in a pipe-hive, while the length is 8.46 ± 0.01 mm., the width is 2.84 ± 0.09 mm., and the number of hooks is 21.81 ± 0.02 , when reared on comb foundation.

The cubital index of the workers emerging in pipe-hives, is ranging between 1.75 and 3.80 with an average of 2.61 ± 0.047 , while it is ranging between 1.63 and 3.60 making an average of 2.50 ± 0.043 in workers emerging from Langstroth combs.

The first wax gland surface is 1.35 ± 0.006 mm. in length and 2.10 ± 0.008 mm. in width when the worker is reared in a pipe-hive while it has

1.47 ± 0.009 mm. in length and 2.27 ± 0.03 mm. in width when reared on comb foundation.

The characteristics of drones

The weights of the Egyptian newly emerging drones are varying from 180 to 230 mgms. The mean weight is 209.58 ± 1.99 mgms. The mean length of the fore-wing is 11.04 ± 0.07 mm., varying from 10.17 to 12.04 mm. The mean width of the fore-wing is 3.56 ± 0.02 mm., varying between 2.3 to 3.79 mm. The hind-wing is attached to the fore-wing by a number of hooks varying from 18 to 25 and their average number is 21.11 ± 0.256 . The cubital index averages 1.52 ± 0.03 , ranging between 1.0 and 2.0.

The weights and the number of ovarioles of the queens

The Egyptian queen-bee has a number of ovarioles varying from 145 to 261 in the two ovaries. The mean number of ovarioles is 192 ± 10.95 . The right ovary consists of 73-139 ovarioles and their mean is 99 ± 6.88 . The left ovary is composed of 72-122 ovarioles and their mean is 93 ± 5.48 . The virgin queens when newly emerging are varying in weights from 82 to 161 mgms. The mean weight is 123 ± 1.8 mgms.

REFERENCES

- Abu-Shady, A.Z. (1949) : Races of bees. The hive and honey-bee (Hamilton, Illinois, pp. 11-20).
- Alpatov, W. W. (1929) : Variability in the honey-bee tongue, biometrically investigated and practical questions connected with the problem of the selection of the honey-bee (*Trans. 4th Intern. Entom. Congress*, 1928).
- Alpatov, W. W. (1932) : Some data on the comparative biology of different races (*Bee World*, XII, No. 3, pp. 128-140).
- Archivfur, B. (1931) : *Apis*, African races (*Bee World*, XII, pp. 25-27).
- Gough, L. H. (1923) : The Egyptian honey-bee, *Apis fasciata* (*Bee World*, IV, pp. 191-194).
- Lovin, D., and Haydak, M. H. (1951) : Seasonal variations in weight and ovarian development of the worker honey-bee (*Jour. Econ. Entom.*, XLIV, pp. 54-57).
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There are some ...

Mosquitoes of the Oases of the Libyan Desert of Egypt

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In all Surveys of the Mosquitoes of Egypt, the Mosquitoes of the Oases play a distinguished part not equalled by those of any other part of the Country, with the exception perhaps of Sinai. The peculiar characters of the oases regarding their isolation, climatic conditions, type of soil, etc., are reflected upon the flora and fauna of the oases and certainly upon mosquitoes.

The present study reviews what is known about the Mosquitoes of the Oases of the Libyan Desert (Siwa, Bahria, Kharga and Dakhla), and includes material obtained at the Insect Control Section, Ministry of Health, during malaria-control projects in the years 1950-1955.

Anophelini

Anopheles (Anopheles) algeriensis Theobald.

This is mostly a Mediterranean species occurring in countries in Europe and in the Middle East.

In his extensive Survey of the Mosquitoes of Egypt, Kirkpatrick (1925) did not find this species but suspected its occurrence in Sinai. Salem (1933) reported a single female, but no larvae, in a big collection of mosquitoes from Sitra near Siwa Oasis. Our investigations at Siwa have revealed that this species is widely distributed in most of the villages of the Oasis and that it forms about 0.02% of the total anopheline larvae collected in the year 1951.

A. algeriensis breeds mostly in seepage water and in drains, and less frequently in irrigation channels, surface water and wells. Seasonal prevalence of larvae is from February to May.

Although 483 larvae of *A. algeriensis* were collected during 1951, yet not a single adult of this species was found among over 34,000 anopheline mosquitoes. In 1952, only two females were found in a similar collection caught from houses, sheds and other familiar resting places. It is assumed that the

adults of this species are wild and seldom enter houses.

It is obvious that *A. algeriensis* in Siwa has no part in transmitting malaria.

Hitherto this species has not been reported, apart from Siwa, from any other region including Sinai.

Anopheles (Myzomyia) pharoensis Theobald.

In the Delta and Nile Valley, this species is widely distributed and most abundant of all anopheline mosquitoes. In Dakhla Oasis, it was recorded by Storey (1918), and in Kharga by Kirkpatrick (1925). Barber and Rice (1937) recorded this species in Siwa Oasis where they found one adult mosquito among a batch of 117. Subsequent surveys of the oasis failed to find it again except for a single 4th. stage larva collected in 1949 from a remote place in South Siwa. *A. pharoensis* was also found to occur in Bahria Oasis.

This species breeds in all collections of water with some vegetation and especially in rice-fields. Its seasonal prevalence coincides with rice cultivation, i.e. from July to October. In Dakhla Oasis, adult catches of *pharoensis* comprise 10.2% of all adult anophelines caught during 1952 from houses and sheds, while larval collections amount to over 50% of the anopheline larvae.

Although Barber and Rice (1937) consider that *A. pharoensis* is an efficient carrier of malaria and has a decided affinity for human hosts, other workers, e.g. Hackett (in Boyd's Malariology, 1949) considers it an ineffective carrier and least domestic of all palaearctic vectors. This latter statement was found to be the case in Dakhla where this species was found, during the day, resting on rice plants.

Precipitin tests of stomach blood showed that of 156 specimens, 155 taken from sheds were positive for blood of ox and only one from a house positive for human blood.

In Egypt, *A. pharoensis* has been found infected in nature during an exceptionally malarious season, the sporozoite index being 1.4% (Madowar, 1936), 0.33% (Barber and Rice, 1937). Number of mosquitoes dissected was 138 and 1573, respectively.

Anopheles (Myzomyia) superpictus Grassi.

This species is rare in Egypt. It occurs in Sinai (Kirkpatrick, 1925) but not in the Delta or the Nile Valley. Salem (1933) reported a few adults from Siwa. Examination of many thousands of larvae and adults collected over three years at the laboratories of the Insect Control Section have failed to detect this species in Siwa. Some worn-out adults, however, were collected in May 1950 and being suspected for *A. superpictus*,

they were sent to London School of Tropical Medicine for identification. Major H. S. Leeson named them *A. multicolor*, but admitted the probable confusion with *A. superpictus*.

It is interesting also to note that neither Kirkpatrick nor Salem were able to distinguish these two species in the larval stage.

Anopheles (Myzomyia) sergenti Theobald.

This is a desert species occurring in Fayoum, Sinai and all the Oases, but scarcely found in the Delta or Nile Valley. Storey (1918) recorded *A. sergenti* from Siwa under the name *A. palestiniensis*. Kirkpatrick (1925) found it in Kharga Oasis and suspected its presence in the other Oases. Subsequently its existence in Siwa, Bahria, Dakhla and Kharga was established and it is known that it is the predominant anopheline species there. In Dakhla it comprises 60.6% of all anopheline catches of the year 1952. Its seasonal prevalence is during autumn and early winter.

A. sergenti breeds in the weedy edges of slowly running water arising from permanent wells and springs. It is also found in rice-field channels, seepage and rarely in weels. *A. sergenti* has been incriminated as a malaria vector in Egypt (Farid, 1940), the sporozoite index being 2.7 (220 mosquitoes examined). The species is fairly domestic and it is considered the main malaria vector in all oases. When this species was eradicated from Dakhla and Kharga Oases during 1948-1949, malaria dropped in Dakhla from 13% (1946) to 02.% (1948) (Shawarbi, in the press).

Anopheles (Myzomyia) multicolor Cambouliu.

This species occurs in the Delta and Nile Valley but it is not as abundant as *A. pharoensis*. It is very common in all the oases and was reported by all workers who surveyed any of these oases for mosquitoes.

A. multicolor breeds chiefly in seepage water with fairly liberal amount of salt. Kirkpatrick mentions that the seasonal prevalence of this species is from July to November, but our repeated findings, however, over more than 3 years and in different localities indicate that it is a spring species common in March and April. This might be attributed, however, to the drying of most of *A. multicolor* breeding places in the oases from May onward.

The role played by *A. multicolor* in malaria transmitting is still doubtful. Storey (1918) and Kirkpatrick (1925) believed it to be the malaria carrier of Egypt. Barber and Rice (1937) succeeded in infecting it in the laboratory with *Plasmodium falciparum*, but they did not find it (neither did we in Dakhla) infected in nature.

Culicini***Uranotaenia unguiculata* Edwards.**

Occurs in Siwa, but never abundant. Larvae are found in August and September and disappear in January and February. Adults do not enter houses. It breeds in pools with vegetation, occasionally in wells. Kirkpatrick (1925) recorded it from Kharga in October. We did not find it in Kharga, nor in Dakhla, and it is reported here for the first time from Siwa.

***Theobaldia longiareolata* Macquart.**

Recorded from Kharga and Bahria (Kirkpatrick, 1925), Siwa and Dakhla (Salem, 1933). More frequently met with than the previous species. Its seasonal prevalence is from November to April and it is rare in summer. Adults are found occasionally in houses, but never known to bite. In the oases, it breeds in seepage and surface water and frequently in unused wells.

***Theobaldia annulata* Schrank.**

This is the first record of this species from Egypt. Few larvae were collected from seepage water near Siwa town during January 1955, together with larvae of *Aedes caspius* and *Theobaldia longiareolata*.

***Aedes caspius* Pallas.**

Abundant in all oases throughout the year but especially during autumn and winter. It is at its minimum in summer (June to September). It breeds in seepage and surface water, and sometimes in rice fields. It enters houses occasionally but frequently met with in large numbers, outdoors at day time where it bites severely.

***Aedes detritus* Haliday.**

Kirkpatrick obtained a single larva of this species, which was successfully bred, at Siwa Oasis. Our investigations there revealed its presence in moderate numbers from February to May, and in lesser numbers in November to January. In summer (June-September), larvae are not found at all. This confirms Kirkpatrick's suggestion that this species breeds in fairly cool weather. *A. detritus* is a salt water breeder. Most of the larvae obtained in one year (378) were from seepage water with a high supply of salt and a few from drains. Females enter houses and like *A. caspius*, it is often found outdoors where it bites by day.

A. detritus is not recorded from Dakhla and Kharga, but found in Bahria.

Culex pusillus Macquart.

The distribution of this species is the same as that of *A. detritus*, i.e. occurring in Siwa and Bahria, but not in Dakhla or Kharga. This too, is a salt water breeder occurring mostly in seepage water and drains. In Siwa, it is also found in wells and channels (Siwa's wells contain a considerable amount of salts). The species is abundant all over the year, except in winter (December-March).

Culex deserticola Kirkpatrick.

This species was first described by Kirkpatrick (1925) from specimens found at the Eastern desert. Subsequently, Salem (1933) found it in Siwa breeding in a salt pool. Our investigations revealed its presence in all the oases, though never abundant. It is not found in houses and not known to bite man.

Culex theileri Theobald.

This species is very common and abundant in the oases (except Siwa), while very scarce in the Nile Valley. It breeds in rice fields, pools and drains with abundant vegetation. In Bahria it is most abundant in July and August. It is met with indoors and is known to bite.

Culex pipiens L.

This species, which is the most abundant mosquito in the Nile Valley, is only scarce in the oases, and it seems that it is replaced there by *Culex theileri*. Few specimens of it are found nearly all over the year in the four oases. It breeds in almost all sorts of fresh water breeding places including pools, wells, containers, etc. This species is the proved carrier of *Wuchereria bancrofti* (Khalil, Halawani and Hilmy, 1932) in the Nile Valley. Its role in the oases has not been investigated owing to its scarcity.

Culex univittatus Theobald.

Recorded by Kirkpatrick from Kharga and Bahria, and by Salem from Dakhla. The present survey confirmed both authors, and revealed its absence from Siwa Oasis. It breeds in pools, wells, drains and rice fields. It is known to enter houses and bite during the evening. This species is also common in the Nile Valley.

Culex tritaeniorhynchus Giles.

This species was recorded from Kharga and Dakhla by Kirkpatrick and Salem, respectively. It also exists in Bahria where it was found in abundance, especially during August and September. Its main breeding places are rice fields and their drains. No adults were found inside houses.

REFERENCES

- Barber, M.A., and Rice, J.B. (1937) : A Survey of Malaria in Egypt (*Am. J. Trop. Med.*, XVII, p. 413).
- Farid, M. (1940) : Malaria infection in *Anopheles sergenti* in Egypt (*Riv. malariologia*, XIX, p. 159).
- Hackett, L.W. (1949) : Malaria Control in the Palearctic Region (in Body's Malariology, Saunders Co., p. 1416).
- Khalil, M., Halawani, A., and Hilmy, I.S. (1932) : On the transmission of *Filariasis bancrofti* in Egypt (*J. Egyptian Med. Ass.*, XV, No. 6, pp. 317-322).
- Kirkpatrick, T.W. (1925) : The Mosquitoes of Egypt (Government Press, Cairo).
- Madwar, S. (1936) : A Preliminary note on *Anopheles pharoensis* in relation to Malaria in Egypt (*J. Egyptian Med. Ass.*, XIX, p. 616).
- Salem, H.M. (1933) : New Records of some Egyptian Mosquitoes (*Bull. Soc. Roy. Ent. Egypte*, XVII, p. 83).
- Storey, G. (1918) : Keys for the determination of Egyptian Mosquitoes and their larvae (*Bull. Soc. Ent. Egypte*, V, p. 84).
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On the mouth parts of the larval instars of *Anopheles quadrimaculatus* (Say)

[Diptera : Culicidae-Anophelini]

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(with 38 Figures)

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I. INTRODUCTION

In this study, the morphology of the head and the mouth-parts of the, larva of *Anopheles quadrimaculatus* (Say) has been discussed.

The four larval instars of this species have been thoroughly studied. It was planned this would enable the writer to point out the most significant instar differences that could be used in the construction of a key.

An important aspect of the study, is the homology of the various parts of the mosquito larval head with those of a generalized insect. The homologies of these parts have been considered by quite a few of the early and recent workers, but have not been entirely satisfactory from the morphological point of view. Because he disagrees to some extent, with the interpretations of some of the previous workers, the author has made an endeavor to compare the possible homologies of the mouth-parts with those of the generalized insects. The introduction of new terms has been avoided; and new terms which had been introduced by previous workers have been disregarded.

II. ACKNOWLEDGMENT

This investigation was conducted at the suggestion of Professor William P. Hayes, the Head of the Department of Entomology at the University of Illinois. His supervision and guidance are gratefully acknowledged.

III. REVIEW OF LITERATURE

The mosquito literature is enormous. However, there are few papers which deal with the larval morphology in general and the mouth parts in particular. Meinert (1886) was the first to work on the external morphology of the larvae of two species of *Culex* and one species of *Anopheles*. His work is considered one of the best and probably, the most clearly illustrated. However, he did not discuss the homologies of the different parts of the head. Raschke (1887) discussed the external and the internal morphology of *Culex nemorosus* (Meigen) as well as the histology of the various tissues. Nuttall and Shipley (1901) published on the morphology of the larval head of *Anopheles maculipennis* (Meigen). Imms (1907) published on the larval and pupal stages of *Anopheles maculipennis* (Meigen). He dealt very little with the mouth parts of the larval stage. Wesché (1910) dealt in some details with the larval and pupal stages of West African Culicidae. Salem (1931) studied the external morphology of the fourth instar larva of *Aedes (Stegomyia) fasciata* (Fab.). He gave a detailed description of the mouth parts. His illustration of a longitudinal section through the complex labium shows the sequence of the different layers of the labium. Cook (1944a) studied the morphology of the larval heads of *Theobaldia incidens* (Thomson), *Anopheles maculipennis* (Meigen), *Lutzia halifaxi* (Theobald) and *Armigeres malayi* (Theobald). His work is considered to be the best and most conclusive of all the work published on that subject. Cook also considered the homologies of the different parts of the larval head with those of other insects. He introduced a number of new terms to name some parts of the labrum and the labium. The writer believes that such new terms as "maxillary plate", "messores" and "aulaeum", are unnecessary, as the homologies of the different parts of the labium and the labrum with those of other insects could be accomplished without them. Dodge (1945), in his short article on the morphology of the larval heads of one species of each of the genera *Anopheles*, *Megarhinus*, *Uranotaenia*, *Mansonia*, *Culex*, *Aedes*, *Psorophora* and *Orthopodomyia*, gave illustrations of the ventral aspects of the heads. Farnsworth (1947), working on the morphology of the larval head of *Anopheles quadrimaculatus*, considered with clear illustrations the various parts of the mouth. She followed, however, the interpretations of Cook (1944a) and

used his new terms. Foote (1952) worked on the larval morphology of *Culex* (subgenus *Melanoconion*). His work does not furnish sufficient detail in regards to obscure points. He merely follows the interpretations of Cook (1944a), whose new terms he used. The writer's own contribution towards the homologies of the various parts of the mouth of *Anopheles quadrimaculatus* with those of the generalized insects, are discussed within the text of this paper.

IV. REARING, FEEDING HABITS, AND TECHNIQUE

It was found rather difficult to rear the larvae of *Anopheles quadrimaculatus* in fairly good numbers in the laboratory. The eggs are dropped in large trays full of tap, or preferably biological water, to which was added a small amount of moldy corn. The corn, as well as plant infusions increase the rate of egg-hatching (Abdel-Malek, 1948). In about 48 hours, depending on the temperature and the moisture, the eggs hatch and the first instar larvae emerge. It was advisable to transfer the first instar larvae to different trays full of tap or biological water and feed them on a suspension of crumbled yeast in water. Concentration of the yeast is dangerous as it would putrify in water, resulting in bacterial growth that will kill the larvae. Aeration is recommended for the survival of the larvae.

The larvae of all the instars are surface feeders. They feed by filtering the yeast particles with the aid of the rapid movement of the labral brushes and the other parts of the mouth.

It was found satisfactory to preserve the specimens in alcohol. However, the mosquito larvae should be killed in hot water before they are transferred to the alcohol. In the majority of cases, the specimens fail to clear properly if they are killed in 70% or 90% alcohol. After being killed in hot water, the specimens are carefully removed with a large medicine dropper to vials containing 70% alcohol, and allowed to remain for at least two hours. The specimens are transferred again to vials containing 95% alcohol. Dissection of the mouth-parts of the larvae was done in glycerine. Beside being useful as a dissecting medium, glycerine has a clearing effect. The specimens were kept for at least two hours in 95% alcohol. The specimens or the parts of the mouth to be studied were lifted with a wire loop or spatula and transferred to a stender dish containing pure beechwood or creosote for clearing. When clearing has been completed, the specimens were transferred to xylene for not more than one minute. Then, they are placed on a clean slide preparatory to permanent mounting in a xylene-soluble medium like Canada balsam. A cover slip is placed on the balsam and the slide is placed for a short while in an oven at 40°C, after which the specimens are ready for study.

V. GENERAL MORPHOLOGY OF THE HEAD OF THE FOURTH INSTAR LARVA

The head capsule is about 0.753 mm. in width. It is roughly triangular, longer than wide and dark in colour. The dorsal surface is composed of the frons (Fig. 2,F) that covers almost the entire dorsum. The frons is bounded cephalad by the fronto-clypeal suture (Fig. 2,FCS) that separates it from the post clypeus (Fig. 2,Poc). Laterally and caudally, the frons is bounded by the frontal sutures. Near the caudal end of the head, the frontal sutures unite at the meson forming a short coronal suture which extends caudad to the margin of the occipital foramen (Fig. 1,OCFr). The coronal suture is not so distinct and, may or may not be present. The larval eyes (Fig. 1,LE) are prominent and situated laterally on the ocular lobes. The heavily pigmented bodies mesad of the larval eyes are the primordial ommatidia of the adult (Farnsworth, 1947). On the ventral side and mesad of the eyes are located the postgenae (Fig. 1,PG). On the meso-ventral aspect and located between the two postgenae is a rectangular-shaped sclerite which has been termed the submentum (Fig. 1,SMt). The sutures which separate, the submentum from the postgenae are termed the submental-postgenal suture (Fig. 1,SPS). Cephalad, the submental-postgenal sutures bend meso-cephalad where they meet the mentum (Fig. 1,Mt) while proximally they bend meso-caudad until they meet the margin of the occipital foramen. At the caudal bend, the posterior tentorial pits (Fig. 1,PT) are situated on either side.

The maxillae (Fig. 1,Mx) are situated on either side of the cephalic part of the head capsule. The mesal margin of the maxilla extends cephalo-mesad towards the maxilla of the other side, leaving an angle between them, in which is located the cephalic part of the labium (Fig. 1,Lb). The mandibles (Fig. 1,Md) are located on either side of the head dorsad of the maxillae. The antennae (Fig. 1,A) are located on the sides of the cephalic part of the head. They are relatively long and bear two short processes at their distal ends which probably are sensory. The labral brushes move rapidly cephalad and caudad, during the feeding process. The clypeus is divided by the clypeal suture (Fig. 2,CS) into the preclypeus (Fig. 2,Prc) cephalad and, the postclypeus (Fig. 2,Poc) caudad. The preclypeus bears a pair of sclerotized and pigmented spines which have been referred to as the preclypeal hairs (Fig. 2,PrcH).

There have been some discussion as to whether the sclerite which is designated here as the frons (Fig. 2,F) is actually the true frons, the clypeus, or the clypeo-frons. Meinert (1886) regards this area as the "scutum of the third metamere". Wesché (1910) refers to it as the "frons". Howard, Dyar, and Knab (1912) term it the "frons or epistoma",

Nuttall and Shipley (1903) call it the "frons". But Cook (1944a) regards it as the "clypeus". Farnsworth (1947), working on the morphology of the larval head of *Anopheles quadrimaculatus*, and Foote (1952), working on *Culex* (subgenus *Melanoconion*), followed Cook's inter-

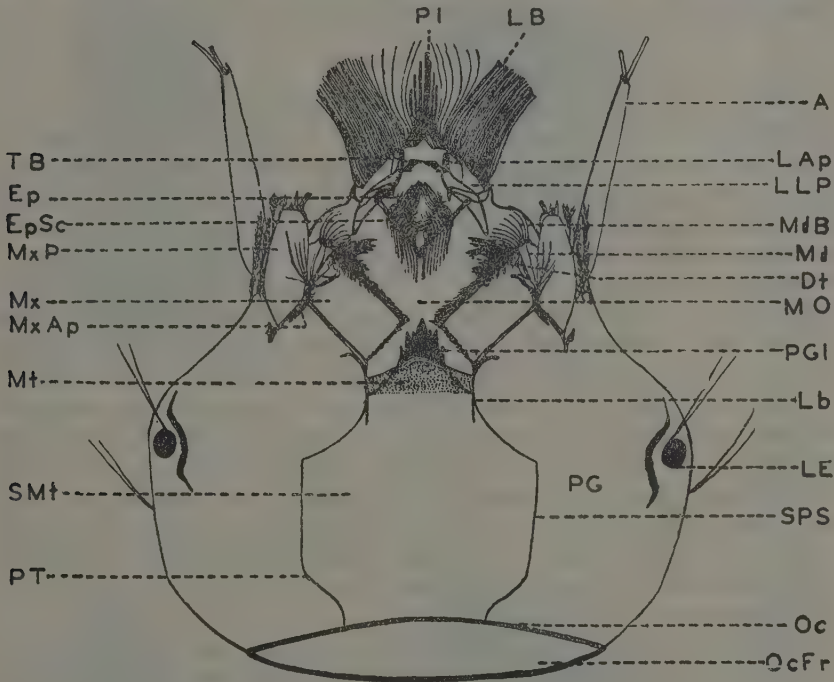


Fig. 1 : The ventral aspect of the head of the fourth instar larva of *Anopheles quadrimaculatus*.

(A, antenna; Ep, epipharynx; EpSc, epipharyngeal sclerite; Dt, dentes; LAp, labral apodeme; Lb, labium; LB, labral brush; LE, larval eye; LLP, lateral labral plate; Md, mandible; MdB, mandibular brush; MO, mouth opening; Mt, mentum; Mx, maxilla; MxAp, maxillary apodeme; MxP, maxillary palpus; Oc, occiput; OcFr, occipital foramen; PG, postgenae; PGI, paraglossa; PI, palatum; PT, posterior tentorial pit; SMt, submentum; SPS, submental-postgenal suture; TB, transverse bar).

pretations. By comparing the head of a generalized insect, with the mosquito larval head, one cannot mistake the frons for the clypeus, and the V-shaped frontal suture for the fronto-clypeal suture, which in most of all cases extends horizontally from one side of the head to the other.

VI. THE MOUTH PARTS OF THE FOURTH INSTAR LARVA

The mouth opening

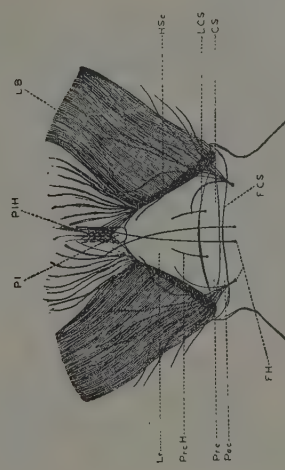
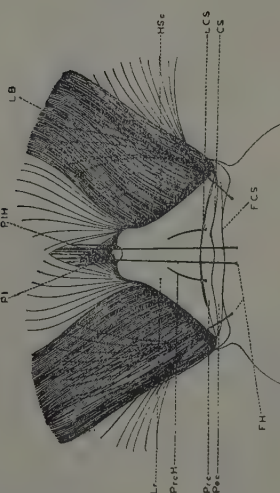
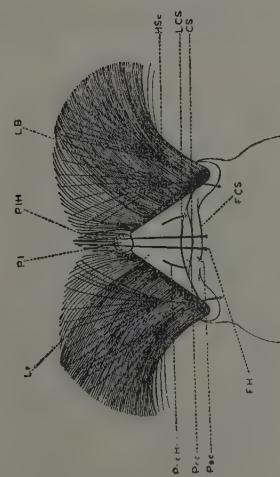
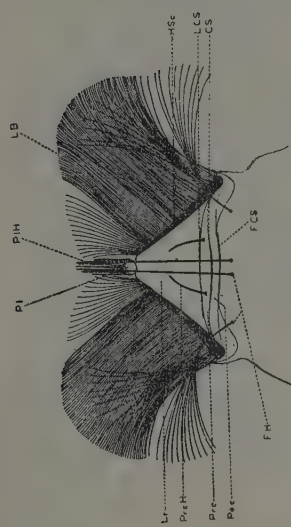
There is no definite mouth opening. It is a space formed by the labrum and the epipharynx above, and the labium and the hypopharynx below, with the mandibles and the maxillae forming the side walls. It could be referred to as an oral cavity. It leads posteriorly to the pharynx.

The labrum

Nuttall and Shipley (1901) described it in the larvae of *Anopheles*, writing: "Between the bases of the brushes is a smaller bunch of hairs, and ventrally there are two semi-circles of hairs, all above, in front of and converging on the mouth. The anterior median area which carried the brushes is called by Meinert the clypeus". Imms (1907) added: "It seems probable that the sclerite should be regarded as clypeo-labrum". Howard, Dyar and Knab (1912), describing it in the larvae of *Culex*, wrote: "Three parts of the labrum can be distinguished, two lateral portions and a median one which projects freely from the anterior margin of the head and has been called palatum". However, Cook (1944a), working on the heads of certain Culicidae, made a revolutionary change in naming the labrum. He referred to the area which is here designated as the preclypeus and postclypeus as the labrum, saying: "This region is all that is left of the dorsal sclerotization of the labrum.... The possibility that it is the anteclypeus seems rather remote". He, therefore, refers to the area cephalad of what he calls the labrum as the palatum. Farnsworth (1947), working on the same species here discussed, followed Cook's interpretations, as well as his nomenclature.

From the writer's own observations, it is evident that the labrum (Fig. 2, Lr) is located cephalad of the preclypeus (Fig. 2, Prc) with the labro-clypeal suture (Fig. 2, LCS) in between. The labrum is composed of three parts, two lateral labral brushes (Figs. 2 and 6, LB) and a disto-median, rounded structure which projects freely at the cephalic end of the head capsule, called the palatum (Figs. 2 and 6, Pl). The palatum is connected with the labro-clypeal suture by means of a more or less triangular membranous area. On the lateral margins of this membranous area are located two pigmented sclerites which carry the labral brushes. They are referred to as the hair-bearing sclerites (Figs. 2 and 6, HSc). On the ental aspect of the labrum, there are five highly sclerotized, heavily pigmented apodemes (Fig. 6, LAp, LLP and TB). They serve as a support for the labral brushes, as well as, for muscle attachments, by means of which the rapid movements of the labral brushes and the palatum are operated, at the time of feeding.

According to Raschke (1887), the term palatum was first used



Figs. 2-5 : Dorsal aspect of the cephalic region of the (2) fourth, (3) third, (4) second, and (5) first larval instars. (CS, clypeal suture; FCS, fronto-clypeal suture; FH, frontal hairs; HSc, hair-bearing sclerite; LB, labral brush; LCS, labro-clypeal suture; Lr, labrum; Pl, palatum; PLH₁ palatal hairs; Poc, postclypeus; Prc, preclypeus; PrcH, preclypeal hairs).

by Linnaeus. It was applied to the median portion of the labrum, between the labral brushes. Since then, it has been used similarly by various authors. In Cook's paper (1944a), he disagrees with the early authors by saying: "This term is improperly applied". He applies this term to the distal area of the head of the mosquito larva, cephalad of what is here designated as the clypeus when the head is in the extended position. He wrote: "....., most of this structure commonly known as the labrum is, in fact, the palatum, but in the sense that it has been employed by us and not as used by early authors". Early in the same year, Cook, working on the morphology and musculature of the labrum and clypeus of insects, used the term palatum for the inner surface of the labrum or for the dorsal wall of the preoral cavity. Contradiction of the two usages of the term "palatum" by Cook (1944a and b) is obvious, even in the sense that has been employed by him.

The palatum of the fourth instar larva of *Anopheles quadrimaculatus* (Figs. 1, 2 and 6, Pl) is small and circular in shape. It bears a number of hairs (Fig. 2, PlH) which are relatively thick and of moderate length. These palatal hairs do not exceed ten in number. The ectal surface of the palatum is coated with very fine, short setae which are hard to see under the dissecting microscope. Arising from the cephalic portion of the frons, are two pairs of frontal hairs (Fig. 2, FH), a mesal pair and a lateral pair. The mesal pair is dark, long, stout, spine-like, and is situated one on each side of the mesal line. The lateral pair, however, is branched. They arise from the cephalo-lateral corners of the frons and spread over the labral brushes, when the labrum is in the extended position. Each one consists of a short stalk, divides into two stems and each divides into several branches.

The labral brushes (Figs. 1, 2 and 6, LB) have also been termed mouth brushes or feeding brushes because of their function. Nuttall and Shipley (1901) wrote: "On the extreme anterior end of the head are the two closely-packed bundles of slightly curved fine, hair-like setae which we have throughout this paper called the brushes". Sale (1931) writes: "The feeding brushes lie, on either side of the ventral surface of the anterior end of the head. Each brush consists of a group of many long curved bristles closely attached in rows along the margin of a chitinous plate". The two labral brushes arise from the two lateral sclerites on the ventral surface of the cephalic part of the head. These sclerites are termed by Thompson (1905) "flabellae" and by Sale (1931) "hair-bearing sclerites". Cook (1944a) termed these sclerites the "penicular areas". Both Sale's and Cook's terms serve the meaning, but the author prefers the term "hair-bearing sclerite" as it is self explanatory. The hair-bearing sclerites (Figs. 2 and 6, HSc) are more or less triangular in shape and heavily pigmented. Two thin flanges separate from them and extend mesad on the ventral side.

Each flange is stiff, rigid and bears a group of relatively short and more or less stout setae or hairs. They extend meso-cephalad and cover almost the whole cephalo-ventral area.

Each labral brush is fan-like in shape and consists of a huge number of closely-packed setae. The setae are simple. They are curved and the degree of curvature differs as we move towards the mesal line. It seems that each brush is composed of five groups of setae. Each group differs from the others in length, curvature and thickness. The first group is the most laterad and is composed of a large number of closely-packed, long, curved hairs which occupy almost the proximal two-thirds of the hair-bearing sclerite. The second group is mesad of the first group and occupies a relatively short part of the hair-bearing sclerite. The setae are less compact, shorter and less curved. The third group is the most mesad and occupies the less sclerotized distal part of the hair-bearing sclerite. The setae are relatively few, short and less curved. The fourth group is composed of short and stout setae which arise from the flange of the hair-bearing sclerite. The fifth group arises from the angle formed by the hair-bearing sclerite and the flange, cephalad of the labral apodeme (Fig. 6,LAp). It consists of few, fine and relatively short setae directed mesad and which overlap each other on the mesal line.

The apodemes of the labral brushes (Fig. 6,LAp, LLP and TB) are internal invaginations situated entad on each side of the cephalic part of the head. These apodemes were first figured by Miall and Hammond (1900). Johannsen (1909) termed them the "black spot areas". Goetghebuer (1912), working on Chironomidae and in 1925 working on nematocerous Diptera, referred to them as the "pre-mandibles". Evans and Patton (1929) believed that the whole apparatus might represent a specialized form of the tormae. Salem (1931) called them "apodemes". Becker (1938) termed them the "longitudinal levers". Cook (1944a) introduced a new term and called them "messores" which he explains as a latin word meaning "harvester". Farnsworth (1947) and Foote (1952) used the new term "messores".

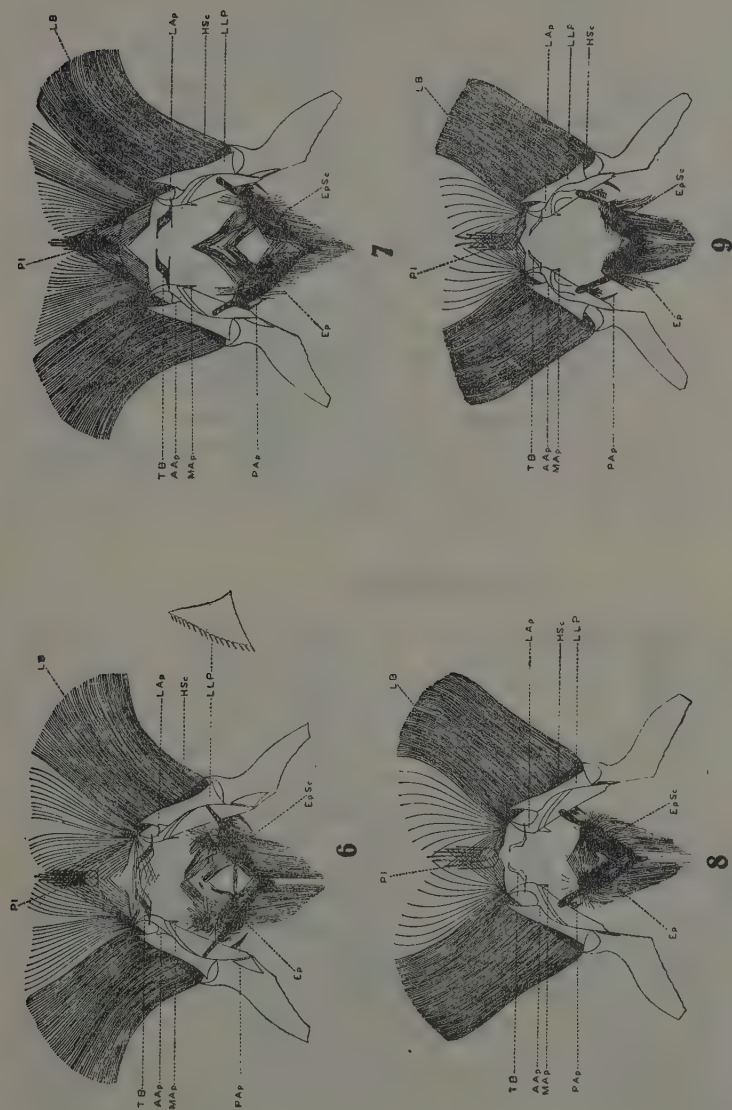
As these structures are invaginations, forming part of the endoskeleton of the head, the writer found no reason to use the new term introduced by Cook (1944a) and called them "apodemes of the labral brushes". The labral apodemes (Fig. 6,LAp) are situated on the ental aspect of the cephalic part of the head, at the base of the hair-bearing sclerite. Each labral apodeme is rod-shaped and extends caudad to the level of the middle part of the lateral border of the mandible. The distal end is pointed and curves laterally to fit into the angle formed by the hair-bearing sclerite and the flange separated from it. The distal third of the apodeme bears two short processes. The anterior process (Fig. 6,AAp) is directed laterad, while the medial process

(Fig. 6,MAP) is directed mesad. The medial process is short with a pointed end. The middle third of the labral apodeme is dilated and heavily sclerotized. It contains a less sclerotized strip that seems to be twisted around the apodeme. It extends meso-cephalad until it connects with the medial process of the labral apodeme. At the proximal end of this part of the apodeme is attached the lateral extremity of the epipharyngeal sclerite (Fig. 6,EpSc). The proximal third of the labral apodeme is less dilated. Connected with that part is a highly sclerotized, spine-like process with a sharp pointed end which is the posterior process of the apodeme (Fig. 6,PAp).

The labral apodeme is separated from the hair-bearing sclerite by a membranous gap which is covered by a triangular plate called the lateral labral plate (Fig. 6,LLP). It has been called "side pieces" by Howard, Dyar and Knab (1912). Becker (1938) called it the "subflabellar sclerite". Salem (1931) termed it the "lateral process of apodeme", while Cook (1944a), Farnsworth (1947) and Foote (1952) termed it the "lateral palatal plate". The lateral labral plate as seen in the figure lies ventrad of the hair-bearing sclerite and dorsad of the labral apodeme, but in nature it lies perpendicular to the labral apodeme. It is triangular in shape with its mesal margin serrated with short and stout dentations seen only under high magnifications. The cephalic portions of the labral apodemes, on each side are connected with each other with a more or less horizontal rod which is called the "transverse bar" (Fig. 6,TB). This bar has been overlooked by the early authors. However, Salem (1931) referred to it as a "transverse chitinous plate connecting the two apodemes". Becker (1938) terms it the "transverse girdle", a term which has been also applied by Farnsworth (1947). Cook (1944a) refers to it as the "anterior palatal bar". Foote (1952) calls it the "posterior ventral margin of the labrum". The transverse bar, however, in *Anopheles quadrimaculatus* is composed of two regions, a cephalic sclerotized region and a caudal more or less membranous region. The mesal ends of the transverse bar in the fourth instar are fused.

The epipharynx

Most of the early workers have overlooked this structure and interpreted it differently. Salem (1931) called it in *Aedes aegypti* the "epipharynx" and called the sclerite which the writer has termed the "epipharyngeal sclerite", the "chitinous bar along the posterior margin of the epipharynx". Becker (1938) referred to the epipharyngeal sclerite as the "endoskeletal arch". Cook (1944a) termed it the "palatal penicular area" and to the epipharyngeal sclerite as the "posterior palatal bar". Farnsworth (1947), working on *Anopheles quadrimaculatus*, follows Cook in naming this structure, but she disagrees with him in the points of the attachments of the



Figs. 6-9: Ventral aspect of the cephalic region of the head of the (6) fourth, (7) third, (8) second, and (9) first larval instars. (AAp, anterior process of apodeme; Ep, epipharynx; EpSc, epipharyngeal sclerite; HSc, hair-bearing sclerite; LAp, labral apodeme; LB, labral brush; LLP, lateral labral plate; MAP, medial process of apodeme; PAp, posterior process of apodeme; PI, palatum; TB, transverse bar).

muscles. Foote (1952), describing it in *Culex* (subgenus *Melanoconion*), referred to the epipharyngeal sclerite as the "palatal bar" and to that peculiar arrangement of setae which are attached to the sclerite as the "palatal brush."

The epipharynx in this species (Fig. 6, Ep) is located on the ental surface of the labrum and covers almost the entire space between the proximal ends of the labral apodemes. It forms the top of the mouth opening, and reaches to the hypopharynx when the mouth is closed. It is composed of two main parts: (a) the epipharyngeal sclerite, and (b) the epipharyngeal hairs.

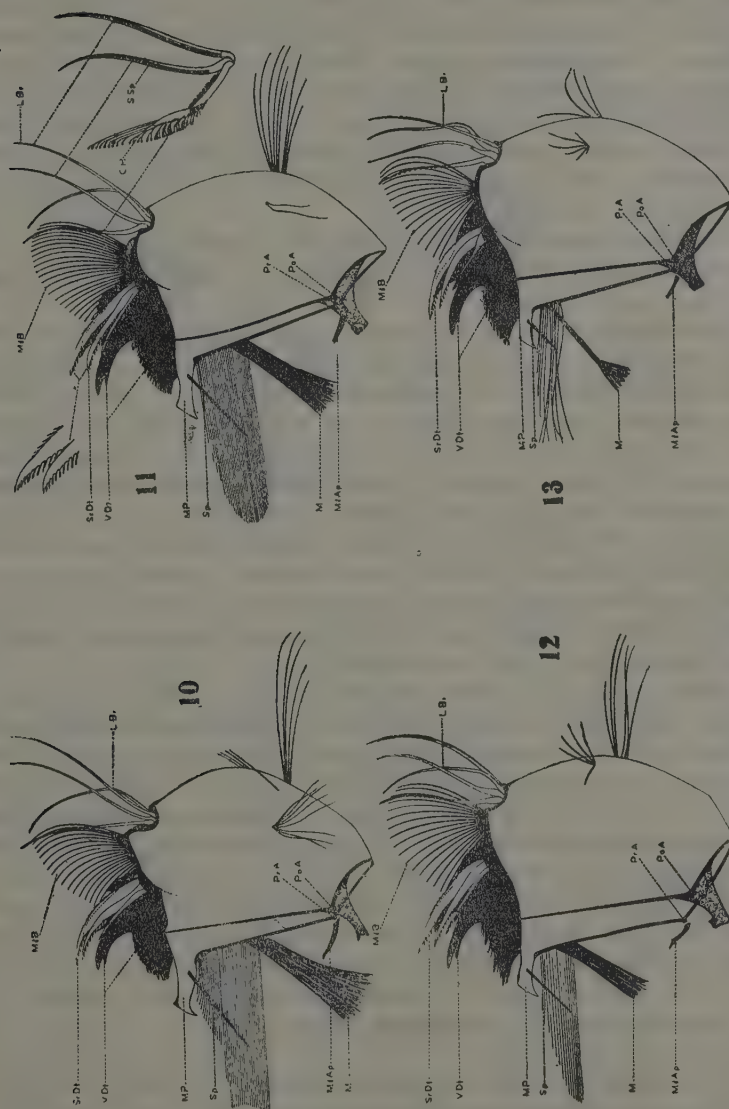
(a) The epipharyngeal sclerite (Fig. 6, EpSc) is V-shaped and extends on the ental surface. Its lateral extremities are attached to the proximal ends of the dilated median third of the labral apodemes. The lateral arms of the epipharyngeal sclerite are dilated in their median part. At the mesal line, the tip of the V is extended posteriorly into a relatively short process.

(b) The epipharyngeal hairs are a peculiar arrangement of hair-like setae which are attached to the epipharyngeal sclerite. These setae are simple, being arranged in 6 or 7 clusters, on each arm of the epipharyngeal sclerite. These setae on each side, tangle and overlap with each other, as well as with those on the other side. On the caudal margin of the epipharyngeal sclerite, just before it reaches the labral apodemes on each side, is attached a bundle of short fine setae. They arise from one point, in the shape of an inverted fan.

The mandibles

The two mandibles (Figs. 10 and 14), together with the two maxillae, form the side walls of the oral cavity. Each mandible bears a set of dentes at its meso-cephalic region, which break up the food particles before they enter the pharynx. The mandible is roughly quadrangular in shape. It is similar to the typical chewing type of other insects. However, it is more specialized than the generalized type. At the meso-cephalic region of the mandible is located the highly sclerotized and heavily pigmented dentes-bearing area. The dentes can be easily differentiated into three categories: (a) a ventral group, (b) a serrated group, and (c) a dorsal group.

(a) The ventral group of dentes (Figs. 10 and 14, VDt) occupies practically the whole sclerotized area at the meso-cephalic region of the mandible. It consists of eight more or less sharp pointed teeth. The most lateral tooth is relatively short. It is followed mesally by two large, long teeth which extend meso-cephalad. They are separated from each other by a space in which is located a short, sharp pointed, spine-like tooth. On a more ventral plane and attached near the distal end of the longest mesal tooth, is a short, triangular tooth which extends mesad (Fig. 10). The meso-cephalic convex margin of the dentes-bearing area bears three short, sharp-pointed teeth, in addition to a group of short setae and spines along the margin.



Figs. 10-13 : Ventral aspect of the left mandible of the (10) fourth, (11) third, (12) second, and (13) first larval instars. (CH, clavate hairs; LBr, lateral bristle; M, muscle; MdAp, mandibular apodeme; MdB, mandibular brush; MP, membranous process; PoA, postarticular process; ArP, prearticular process; Sp, spines; SSp, small spinulae; SrDt, serrated denticles; VDt, ventral denticles).

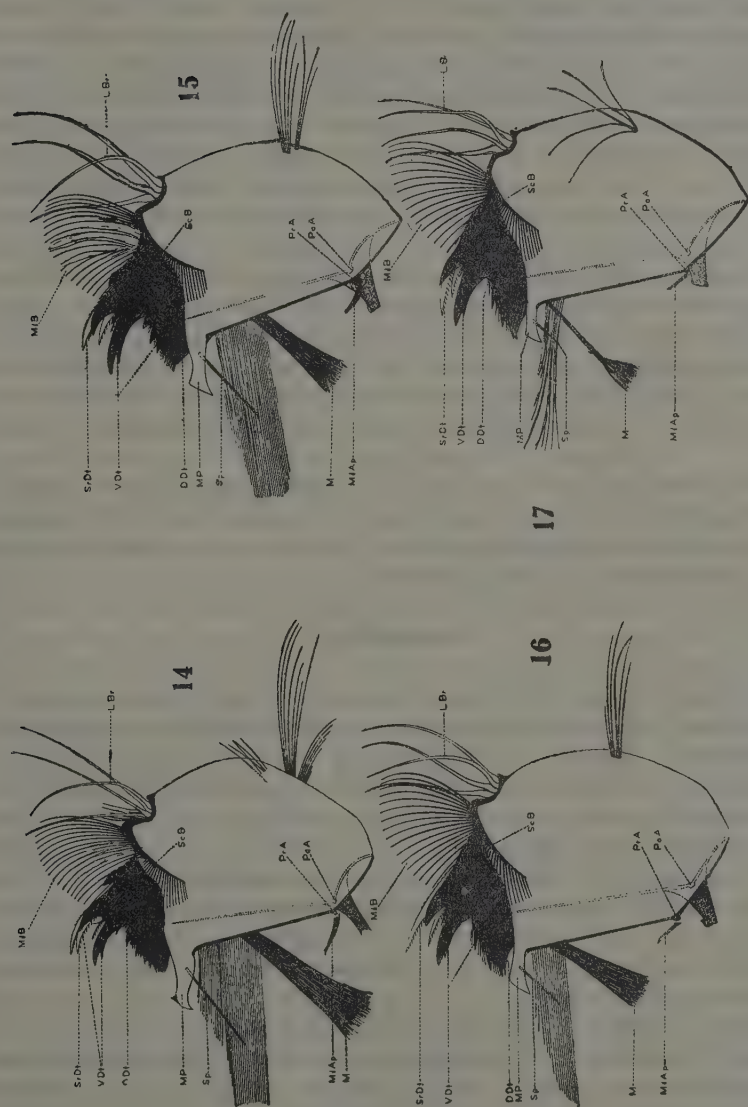
(b) The serrated group of dentes (Figs. 10 and 14, SrDt) consists of three dentes. They are located on a more ventral plane than the ventral group of dentes. They arise from a more or less elevated, and oval shaped sclerite, located caudad of the lateral short tooth of the ventral dentes. They overlap each other at their proximal portions. The lateral tooth is relatively broad and long with its mesal margin serrated with short and uniformly thick processes. The proximal two-thirds of its lateral margin is also serrated. The medial tooth, however, is shorter than the lateral one, having only its mesal margin serrated. The mesal tooth is relatively short and slender, with its mesal margin only serrated.

(c) The dorsal dentes (Fig. 14, DDt) are ten in number. The lateral ones are large with a broad base, and the mesal ones are small with a short base which overlap each other mesally.

At the cephalic end of the mesal margin and caudad of the dentes-bearing area is located a more or less membranous process that extends mesad, which the writer has referred to as the membranous process (Figs. 10 and 14, MP). There is a long sclerotized spine (Figs. 10 and 14, Sp) extending meso-caudad which is attached near the proximal end of the ventral surface of the membranous process. The mesal margin of the mandible is highly sclerotized and heavily pigmented along its entire length. This sclerotization has been homologized by Patton and Evans (1929) with the mola of the mandible of the cockroach. There is an enormous number of long setae extending mesad which are attached to the distal half of the mesal margin. The abductor muscle (Figs. 10 and 14, M) is attached to the middle part of the mesal margin and extends meso-caudad.

According to Cook (1944a), describing the mandibular articulation in *Anopheles maculipennis*, the anterior mandibular articulation is located on the cibarial bar, while the posterior articulation is formed by an elongate arm developed from the mandible itself which extends to the ventral wall of the head. Farnsworth (1947) also states that this elongate arm which forms the posterior mandibular articulation extends around the base of the maxillary palpus to aid in its support. The mandible actually articulates to the cranium by two artes, an ectal preartis (Figs. 10 and 14, PrA) and an ental postartis (Figs. 10 and 14, PoA). A mandibular apodeme (Figs. 10 and 14, MdAp) is attached to the preartis. Developing from the caudal end of the mesal margin, on both sides of the postartis, is a tendon-like structure. It extends around the base of the maxillary palpus and attaches to the head, thus serving for its support.

The lateral margin of the mandible is convex. It bears on its proximal third a group of fine setae extending laterad which range from six to ten in number. There are a few short and fine setae which arise from the lateral region. At the cephalic end of the lateral margin is located a heavily



Figs. 14-17 : Dorsal aspect of the right mandible of the (14) fourth, (15) third, (16) second, and (17) first larval instars. (DDt, dorsal denticles; LBr, lateral bristle; M, muscle; MdAp, mandibular apodeme; MdB, mandibular brush; MP, membranous process; PoA, postarist; PrA, prearist; ScB, sclerite bearing brush; Sp, spines; SrDt, serrated denticles; VDt, ventral denticles).

pigmented and sclerotized socket which bears the lateral bristles (Figs. 10 and 14, LBr). The lateral bristles are long and are four in number. The most mesal bristle is shorter than the rest of the bristles and seems to be divided into three segments. The distal segment of which, is short, slender, and bears small clavate hairs (Fig. 11, CH) that extend meso-cephalad. Both the long distal clavate hairs and the short proximal ones are divided distally into two or three branches which are short and clavate. The median segment of the most mesal bristle, bears on its mesal margin a group of short and branched clavate hairs. There are a few branched non-clavate hairs at the proximal end of this median segment. There are also a few very short non-branched clavate hairs. The proximal segment is the longest, bearing on its lateral margin a great number of very fine and short setae. The function of the clavate hairs is not known, but they may possibly have a sensory function. The other three lateral bristles are elongate, curved and with pointed distal ends. The mesal surface of each has two longitudinal rows of small spinulae (Fig. 11, SSp). These four lateral bristles have been homologized by Patton and Evans (1929) with the palp of the mandible of Crustacea.

The mandibular brush (Figs. 10 and 14, MdB) consists of a great number of curved, rigid setae. Laterally the setae are long and curved which become shorter and somewhat straight mesad. The brush arises from a sclerite (Fig. 14, ScB) which is heavily pigmented.

The maxillae

The maxillae (Fig. 19) are located on each side of the head, ventrad of the mandibles. In the angle between the two maxillae lies the cephalic part of the labium. It is easily noticed that the maxilla of the larva of *A. quadrimaculatus* has departed radically from the generalized type of maxilla. That happens by reduction from the generalized type, or by suppression of one or two of the lobes forming the maxilla (Snodgrass, 1935). Cook (1944a), working on *A. maculipennis*, said that the maxilla is composed of two parts, the maxillary palpus and the stipes which may or may not include the galea or lacinia. Farnsworth (1947), working on *A. quadrimaculatus*, stated that the maxilla is made up of the palpus and the stipes which may include the galea or lacinia.

According to my observations, the maxilla is more or less trapezoidal in shape. It is composed of two major parts, the cardostipes, and the palpus. The cardostipes (Fig. 19, CdSt) which is the fused cardo and stipes, has been called the stipes by Cook (1944a) and Farnsworth (1947). The cardostipes is flat and more or less rectangular in shape. It is clothed on both the ventral and the dorsal side by numerous fine setae. Both the cephalic

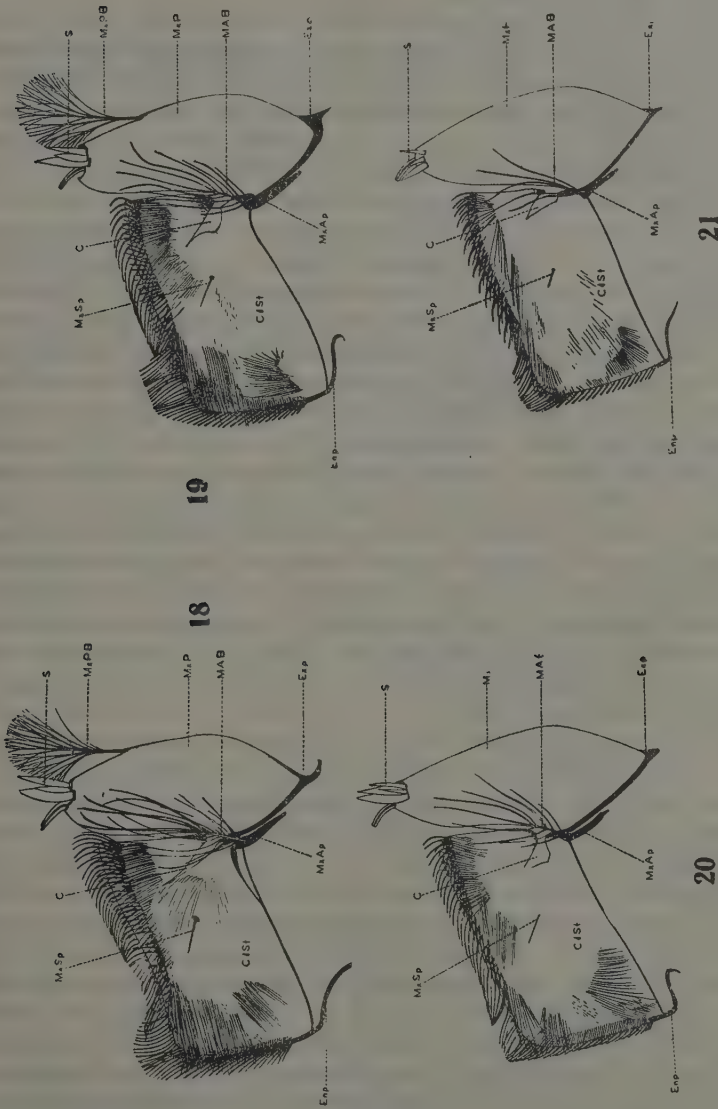
and mesal margins of the cardostipes are bordered with stout setae. The setae arising from the cephalic margin are of moderate length and are curved mesad. There are stout, straight and shorter setae that tangle and overlap the curved ones. Arising from the mesal end of the cephalic margin are fairly long stout setae that are slightly curved. Most of these setae, however, tangle and overlap each other to form a sieve-like structure. Along the mesal margin of the cardostipes arise short but stout setae which extend mesocephalad. The various groups of fine hairs which cloth the ventral surface of the cardostipes differ much in length, direction and density. Near the proximal end of the mesal margin is attached a sclerotized area which extends caudad to form a sclerotized pigmented rod. It then extends laterally until it articulates with another sclerotized rod which extends upwards, and forms the mesal point of articulation. The caudal margin of the cardostipes is sclerotized along its entire length. A maxillary spine (Fig. 19, MxSp), arises from the middle of the ventral aspect of the cardostipes, which is pigmented and of moderate length. The proximal end of the lateral margin of the cardostipes is pigmented, more or less sclerotized and bears a cleft (Fig. 19, C). The cleft is narrow with a pointed end and extends mesocephalad.

The maxillary palpus (Fig. 19, MxP) is large and wide and attached to the lateral aspect of the cardostipes. It is highly developed and long enough to extend cephalad beyond the cardostipes. It is dilated in the middle and tapers at its proximal end. The proximal end is more or less sclerotized on its outer and inner margins. The sclerotization extends caudad forming a short sclerotized rod which serves as the lateral point of articulation with the ventral wall of the head. Arising from the distal end of the palpus, are five papilliform structures which are here referred to as the sensoria (Fig. 19, S), because of their possible sensory function. The two mesal sensoria are comparatively short and slender. The three lateral ones are elongated and oval in shape but are different in size and length. Cook (1944a), working on *A. maculipennis*, and Farnsworth (1947), working on *A. quadrimaculatus*, did not give much consideration to these structures. Fote (1952), working on *Culex* (subgenus *Melanoconion*), described them as "spines". From the proximal end of the distal third of the lateral margin of the palpus, is developed a characteristic branched bristle (Fig. 19, MxPB). It arises on a more or less elevated area. Because of the absence of this tree-like bristle in other species or genera, it is considered to be of a taxonomic importance for this species. In the angle between the cardostipes and the palpus is located a heavily pigmented and sclerotized invagination from the ventral wall of the head which is here referred to as the maxillary apodeme (Fig. 19, MxAp). Arising from the distal end of the maxillary apodeme is a relatively short, stout and plumose bristle (Fig. 19, MAB). It lies obliquely across the cardostipes and the palpus at their point of attachment.

Concerning the points of articulation of the maxilla to the ventral wall of the head, C o o k (1944a), describing them in *A. maculipennis*, stated that the stipes (cardostipes) articulates with the cranium along its whole length. He also mentioned that one specific articulatory point is developed at the inner edge where a C-shaped thickening appears in a plane parallel to the labium. F a r n s w o r t h (1947), working on *A. quadrimaculatus*, also described the sclerotized arm at the caudal end of the mesal margin of the cardostipes as extending laterad to articulate with another rod which extends upwards from a point laterad to the attachment of the prementum with the maxillary segment (submentum). From the writer's observations, however, it is apparent that the maxilla articulates to the cranium at two points, a mesal and a lateral point. They are referred to as the entoparartis (Fig. 19,Enp), and the exoparartis (Fig. 19,Exp). The cardostipes, however, is articulated to the ventral wall of the head along its entire caudal length. The articulation is strengthened by the maxillary apodeme (Fig. 19,MxAp). As the cardo is the sclerite of the maxilla which usually bears the points of articulation, I believe that the stipes of C o o k (1944a), F a r n s w o r t h (1947) and F o o t e (1952), to be a fused cardostipes.

The labium

The labium (Fig. 1,Lb) is a complicated structure and consists of several parts. Early and recent authors, have tried to homologize these parts with the parts forming a generalized labium, but the result was found to be confusing. N u t t a l l and S h i p l e y (1903), working on *A. maculipennis*, wrote: "There is nothing which can be homologized with the second pair (of maxilla)". I m m s (1907), in his description of the same structures in the larvae of *Anopheles*, said: "Between the two maxillae there lies a pointed toothed plate. It is termed by M e i n e r t the "underlip" and by F e l t (1904) "the labial plate"; the latter writer figures it for the larvae of large number of North American Culicidae". C o o k (1944a), working on the mouth-parts of certain Culicid larvae, made a revolutionary change in interpreting the different parts of the labium. He called the median area, which has been termed by H o w a r d, D y a r and K n a b (1912) as the mentum, "the maxillary plate". He wrote: "It is our conclusion, however, that this structure is formed by the maxillary segment which has expanded beyond its usual limits". C o o k also introduced another new term, the "aulaeum", for the structure which is here designated as the glossa. He stated that the aulaeum is only developed in Culicidae. F a r n s w o r t h (1947), working on *A. quadrimaculatus*, applied the term maxillary plate to that sclerite located on the mid-ventral surface of the head, which has been homologized with a mentum by H o w a r d, D y a r and K n a b (1912).



Figs. 18-21 : Ventral aspect of the left maxilla of the (18) fourth, (19) third, (20) second, and (21) first larval instars. (C, cleft; CdSt, cardostipes; Exp, entoparatus; Eap, exoparatus; MAB, maxillary apodeme bristle; MxAp, maxillary apodeme; MxP, maxillary palpus; MxPB, maxillary palpal bristle; MxSp, maxillary sensory spine; S, sensoria).

She also homologized the "aulaeum", (Cook, 1944a), with the submentum, and the plate dorsad of it with the mentum and the most dorsal, sclerotized, toothed plate with the prementum.

From the writer's observations, the labium is composed of four parts.

(a) The submentum (Fig. 1, SMT), covering the meso-caudal region of the ventral surface of the head capsule. It is separated from the postgenae (Fig. 1, PG) by, more or less, longitudinal sutures which are bent meso-cephalad distally and meso-caudad proximally. At the caudal bends are situated the posterior tentorial pits (Fig. 1, PT). These sutures here referred to, are the submental-postgenal sutures (Fig. 1, SPS). Snodgrass (1935), in describing the submentum, stated: "The proximal angles of the postmentum (or of the submentum) generally preserve the primitive close association of the labial base with the posterior tentorial pits; but they may become far removed from the foramen magnum if the postgenal regions of the cranium are elongate, or especially when a gular plate bridges the space between the postoccipital margin proximal to the labium". The submentum, however, has received several names. Meinert (1886) called it the "scutum of the second metamere". Raschke (1887) called it the mentum or "kinn". Imms (1907) designates this structure as the "submentum". Howard, Dyar and Knab referred to it as the "mentum". Cook (1944a), Farnsworth (1947) and Foote (1952) termed it the "maxillary plate". Dodge (1945), in his work on the morphology of the mosquito larval head, has referred to it as the "gula" and its lateral boundaries as the "gular sutures". A gula has only been described in Coleoptera, Trichoptera and some Neuroptera. It has never been known to occur in Diptera. Therefore the term gula is not applicable in the mosquito larval head.

The term "maxillary plate" of Cook (1944a) has been erroneously applied. According to De La Torre-Bueno's Glossary, the maxillary plate is found only in Homoptera and he defines it as "the plate next posterior to the lorum and continuous dorsally with the cranial wall". Apparently, this definition and Cook's usage of that term do not coincide. To prove his point of view Cook (1944a) said: "It is our conclusion, however, that this structure is formed by the maxillary segment which has expanded beyond its usual limits.....Evidence to support this contention is derived from the fact that the sutures that define it laterally are the premaxillary sutures". It is quite obvious that the proof given by Cook is not reliable. Evidence to support the fact that the sutures bounding it laterally are the premaxillary sutures is lacking. Embryologically, the rudiments of the first pair of maxillae on the side of the body of the embryo (Wheeler, 1893) give rise after hatching to a pair of maxillae on either side of the head. While the rudiments of the second pair of the maxillae unite along the mid-ventral line to

give rise after hatching to the labium. The median suture which extends along the mid-ventral line of the submentum, but absent in the species here discussed, is a result of incomplete fusion.

(b) The *mentum* (Fig. 1, Mt, and Fig. 23) is located at the distal margin of the submentum. It is narrow, more or less membranous, and triangular in shape with a wide base and a prominently convex margin. The suture between the mentum and the submentum is very hard to see except under high magnification.

There are two, more or less, triangular plates extending cephalad beyond the mentum and located dorsad of it. The most ventral plate is slightly sclerotized and lightly pigmented, while the dorsal one is highly sclerotized, heavily pigmented and strongly armed with teeth. To try to give the exact or the most reasonable homology of these two parts is a difficult task. It is known that the labium of a generalized insect is composed of three main parts and a pair of appendages which are as follows: the submentum, the mentum, the ligula and the labial palpi. In all the genera of the mosquito larvae that I have studied, no trace has been found of any appendages corresponding to the labial palpi. The ligula is a compound organ (C o m s - t o c k , 1949). In the case of the cockroach, the ligula is deeply cleft giving rise to four lobes, the mesal pair is the glossae, while the lateral pair is the paraglossae. The writer believes that the two parts dorsad of the mentum would correspond to the ligula in other insects. Thus, it is most probable that the most ventral plate is the fused pair of glossae, while the dorsal plate is a fused pair of paraglossae which have shifted to a more dorsal position.

(c) The *glossa* (Fig. 27) has been overlooked by some workers. H o - w a r d , D y a r and K n a b (1912) referred to the parts cephalad of the submentum as "excrescences of the mentum". S a l e m (1931) refers to it as the submentum. C o o k (1944a) introduced a new term and called the glossa the "aulaeum" which is a latin word meaning a curtain or canopy. It seems that the introduction of a new term here is unnecessary and the term aulaeum should be disregarded. F a r n s w o r t h (1947) referred to the glossa as the submentum. F o o t e (1952) called it the aulaeum after C o o k (1944a). The glossa (Fig. 27) is triangular in shape, slightly sclerotized and lightly pigmented. It is located ventrad of the paraglossa (Fig. 31) and dorsad of the mentum (Fig. 1, Mt and Fig. 23). It consists of eight tooth-like blunt processes, four on each side, providing perfect symmetry of both sides. Therefore it seems that this is a structure composed of two glossae that have fused with each other along the mesal line.

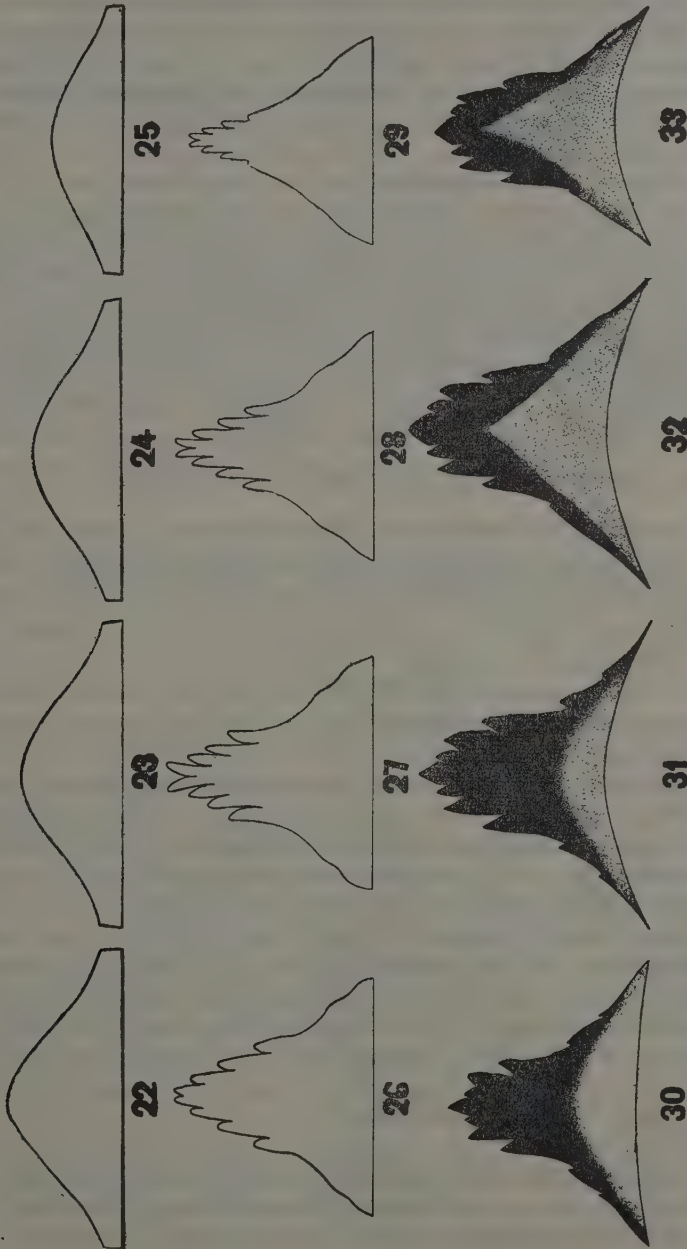
(d) The *paraglossa* (Fig. 1, PG1 and Fig. 31), has been given different names by various authors. M e i n e r t (1886) called it the "under lip", while T h o m p s o n (1905) called it the "mental sclerite". F e l t (1904) terms it the "labial plate". S a l e m (1931) homologized it with the

submentum. Farnsworth (1947) and Foote (1952) referred to it as the "mentum". The paraglossa is armed laterally with strong, sharp pointed teeth. The teeth are 11 in number, five on each side of the larger, disto-central tooth. The paraglossa and the mandibles constitute the main crushing apparatus of the mouth of the mosquito larva. The fact that the teeth on each side are symmetrical in number, size, shape and location, seems to provide good evidence that the paraglossa is composed of two paraglossae which have shifted dorsad of the glossa and became fused along the mesal line. Farnsworth (1947), working on *A. quadrimaculatus*, stated that the mentum (paraglossa) bears only four lateral teeth on each side of the large central tooth.

The hypopharynx

The hypopharynx (Fig. 35) is located dorsad of the paraglossa, where it forms the floor to the mouth cavity. Some authors considered it a part of the labium. Johanssen (1903) and Imms (1907) termed it the hypopharynx. Wasché (1910) says : "At its back are muscular and glandular (?) structures, and passing into it is the pharynx. I shall content myself with figuring this part as I have found it in one species". Cook (1944a), Farnsworth (1947) and Foote (1952) referred to it as the prementum and maintained that the hypopharynx is the portion dorsad of the salivary opening.

From the writer's observations, the whole structure dorsad of the paraglossa seems to constitute the hypopharynx. The route of the salivary duct is not straight (Salem, 1931). It traverses through the whole basal part of the hypopharynx but shifts dorsad before it terminates cephalad towards the disto-cephalic edge. Snodgrass (1935) said : "The salivary syringe of Diptera and of Hemiptera is evidently also a derivative of the salivarium, though in these orders it has a terminal outlet duct that traverses the hypopharynx and opens on the tip of this organ". The hypopharynx (Fig. 35) is square in shape and is attached to the cibarial bars (Fig. 35,CB) at its disto-lateral ends. It is bounded, laterally, by two heavily pigmented and sclerotized rods which are connected cephalad with the cibarial bars. Near the cephalic end, the lateral boundaries are directed mesad into two transverse ridges (Fig. 35,TR). These transverse ridges are pigmented, sclerotized, pointed and extend mesad. Cephalad of the transverse ridges is located a less sclerotized narrow area, with two lobe-like structures (Fig. 35,L) at its lateral extremities. Between these two lobes, extend three transverse rows of microspines (Fig. 35,MSp). The two caudal rows are not complete. In between these two latter rows and situated on the mesal line is the terminal opening of the salivary duct (Fig. 35,S0). The rest of the hypopharynx.



Figs. 22-25 : Ventral aspect of the mentum of the (22) fourth, (23) third, (24) second, and (25) first larval instars. — Figs. 26-29: Ventral aspect of the glossa of the (26) fourth, (27) third, (28) second, and (29) first larval instars. — Figs. 30-33: Ventral aspect of the paraglossa of the (30) fourth, (31) third, (32) second, and (33) first larval instars.

caudad of the transverse ridges, is pigmented, sclerotized and armed with teeth and spines. Along the mesal line, cephalad, are located three pigmented strong teeth. Laterad of these teeth the whole area is covered with spines, which are here referred to as the hypopharyngeal spines (Fig. 35, HypSp). Arising from the meso-caudal region is a prominent heavily pigmented and sclerotized cross-shaped structure. It is somewhat elevated. The cephalic arm of the cross is formed by a strong, long and blunt mesal spine (Fig. 35, MsSp). The lateral arms are provided with an asymmetrical arrangement of spines, four on one side and three on the other (Fig. 35, LSp). On both sides of the caudal arm is located a membranous, unpigmented area which is bounded laterally with dark bands. The angles between the lateral and the caudal arms, on both sides, are occupied by more or less circular and unpigmented sclerites which bear two pairs of movable spines (Fig. 35, MvSp). The general organization of the hypopharynx differs greatly among different species, to be of considerable taxonomic importance.

VII. THE MOUTH PARTS OF THE THIRD INSTAR LARVA

The head of the third instar larva of *A. quadrimaculatus* is about 0.445 mm. in width. It is less sclerotized and less pigmented than that of the fourth instar. The larva in the third instar has the same feeding habits of the fourth instar larva.

The labrum

The labrum (Fig. 3, Lr), as in the fourth instar, is composed of the palatum and the two labral brushes.

(a) The palatum (Figs. 3 and 7, Pl) is similar in shape to that of the fourth instar although it is smaller in size. The palatal hairs (Fig. 3, PIH) are seven in number, while those of the fourth instar are eight. The hair-bearing sclerite (Figs. 3 and 7, HSc) is narrowly triangular in shape; but less sclerotized and less pigmented than that of the fourth instar.

(b) The labral brushes (Figs. 3 and 7, LB) are not as closely packed with setae as those of the fourth instar. Each brush is composed of four groups of hairs. The fifth group which was described in the fourth instar is absent in the third. The two pairs of frontal hairs (Fig. 3, FH) arising from the distal region of the frons (Fig. 3, F) are similar to those of the fourth instar. The lateral branched pair, however, is slender, relatively short and consists of a few branches.

The apodemes of the labral brushes: Both the labral apodemes and the lateral labral plates (Fig. 7, LAp and LLP) are similar in shape and structure to those of the fourth instar. They are, however, less sclerotized and less pigmented. The transverse bar (Fig. 7, TB) is, to some

extent, different from that of the fourth instar. It is composed of two symmetrical halves which do not fuse at the meson, as in the fourth instar. Each half is composed of a more or less sclerotized and pigmented bar-like structure that ends mesad in a sharp point. The caudal membranous part which has been described in the fourth instar, is absent in the third instar.

The epipharynx

The epipharynx (Fig. 7, Ep) forms the upper roof of the mouth as in the fourth instar. The angle between the arms of the epipharyngeal sclerite (Fig. 7, EpSc) is smaller than that of the fourth instar. Each arm, however, is dilated medially and different in shape from that of the fourth instar. The epipharyngeal hairs (Fig. 7, EpH), however, are shorter and relatively fewer in number than those of the fourth instar. The small, fan-shaped group of short setae which is located in the angle between the epipharyngeal sclerite and the labral apodeme which was described in the fourth instar is present also in the third instar, but less prominent.

The mandibles

The mandibles (Figs. 11 and 15) are similar in shape to those of the fourth instar, though they are less sclerotized and less pigmented. The ventral group of dentes (Figs. 11 and 15, VDt) is composed of eight dentes arranged in the same way as in the fourth instar. The serrated dentes (Figs. 11 and 15, SrDt), however, are less sclerotized and more slender than those of the fourth instar. The dorsal dentes (Fig. 15, DDt) are different in shape, size and fewer in number than those of the fourth instar. They consist of only seven teeth. The membranous process (Figs. 11 and 15, MP) is different in shape than that of the fourth instar. The mandible is articulated to the ventral wall of the cranium by the preartis and the postartis (Figs. 11 and 15, PrA and PoA). The hair-like setae which arise from the lateral region, as well as from the lateral margin are shorter and fewer in number than those of the fourth instar. Other than being a little shorter and a little lighter in colour, the lateral bristles (Figs. 11 and 15, LBr) look the same as those of the fourth instar. The mandibular brush (Figs. 11 and 15, MdB), though consists of a fewer number of setae, is similar in shape and structure to that of the fourth instar.

The maxillae

The maxillae (Fig. 19) are similar in shape and structure to the maxillae of the fourth instar, but smaller in size and less sclerotized. Each maxilla is articulated to the ventral wall of the cranium by means of the entoparartis

and the exoparartus (Fig. 19,Enp and Exp) as in the fourth instar. The trapezium shaped cardostipes (Fig. 19,CdSt) is small in size and slightly sclerotized. The maxillary spine (Fig. 19,MxSp) is also short and lightly pigmented. The cleft (Fig. 19,C) in the lateral margin of the cardostipes near the latero-proximal end, is shorter and different in shape from that of the fourth instar, as it is wider in the middle and sharply pointed at the distal end.

The maxillary palpus (Fig. 19,MxP) bears at its distal end five sensoria (Fig. 19,S) as in the fourth instar; though they are smaller in size and lighter in colour. The tree-shaped maxillary palpal bristle (Fig. 19,MxPB) is lighter in colour and consists of a fewer number of branches. It must be mentioned also that the plumose bristle (Fig. 19, MAB) consists of a fewer number of branches which are not as long as those of the fourth instar. Generally speaking, it is not easy to differentiate between the maxillae of the third and the fourth instars.

The labium

The labium is constructed of the same parts as in the fourth instar, with slight differences. The submentum is similar to that of the fourth instar and occupies most of the meso-caudal region of the ventral aspect of the head.

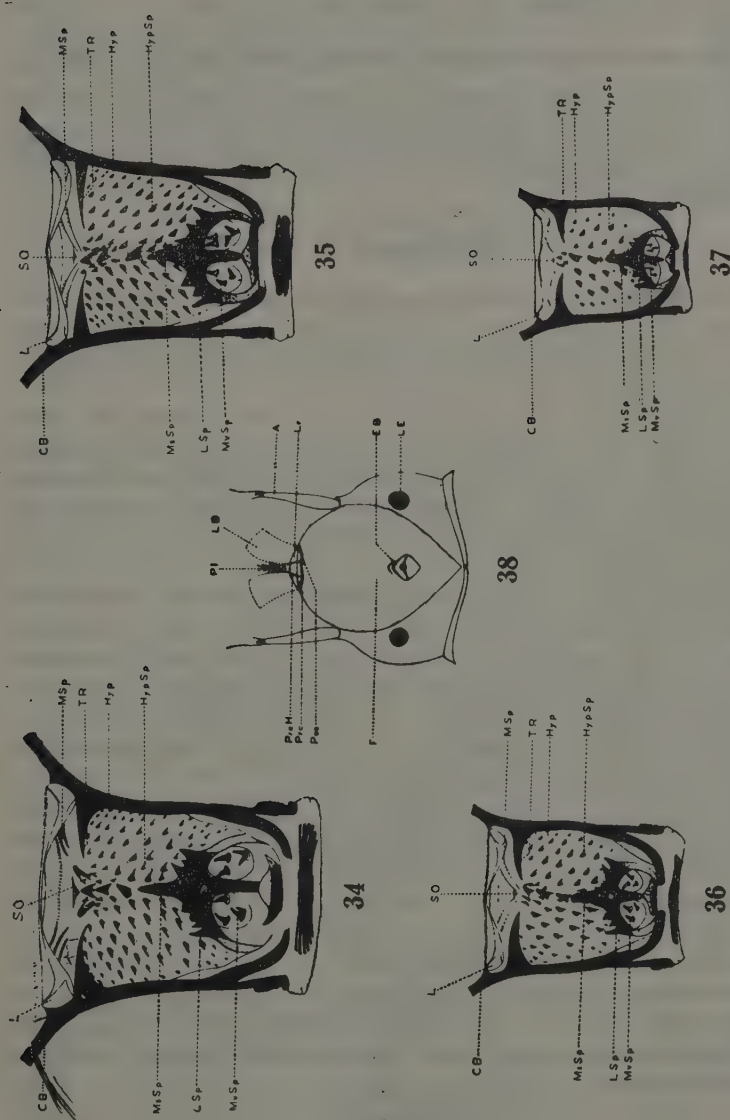
The *mentum* (Fig. 23) is narrower and smaller in size. The cephalic margin of the mentum is not as sharply convex as in the fourth instar.

The *glossa* (Fig. 27) is less sclerotized, less pigmented and smaller in size than the glossa of the fourth instar; but consists of the same number of teeth.

The *paraglossa* (Fig. 31) consists of 11 teeth, five on each side of the large disto-central tooth, as in the fourth instar. In the third instar the paraglossa is smaller in size and less pigmented.

The hypopharynx

The hypopharynx (Fig. 35) is similar in shape to that of the fourth instar; but smaller in size and less pigmented. The transverse ridges (Fig. 35,TR) are more slender than those of the fourth instar. The salivary duct opening (Fig. 35,SO) is small and not quite prominent. The three, more or less horizontal rows of microspines which were described in the fourth instar are reduced to two rows in the third instar, with each row containing only five or four microspines (Fig. 35,MSp). The two lateral lobes (Fig. 35,L) are smaller than those of the fourth instar. The hypopharyngeal spines (Fig. 35,HypSp) are also fewer in number than those of the fourth instar. The lateral arms of the cross-shaped sclerotized area bear six spine-like teeth (Fig. 35,LSp), three on each arm. In the fourth instar, they bear seven teeth,



Figs. 34-37 : Ventral aspect of the hypopharynx of the (34) fourth, (35) third, (36) second, and (37) first larval instars. —
 Fig. 38 : Dorsal aspect of the head of the first instar larva.
 (A, antenna; CB, cibarial bar; EB, egg burster; F, frons; Hyp, hypopharynx; HypSp, hypopharyngeal spines; L, lobe; LB, labral brush; LE, larval eye; Lr, labrum; LSp, lateral spines; MSp, microspines; MSp, mesal spine; MSp, movable spine; Pl, palatum; Poc, postclypeus; Prc, prechypeus; TrcH, predypeal hairs; SO, salivary opening; TR, transverse ridge).

four on one arm and three on the other. The movable spines (Fig. 35, MvSp) are seven in number, four on one side and three on the other; while in the fourth instar, they are eight, four on each side.

VIII. THE MOUTH PARTS OF THE SECOND INSTAR LARVA

The head of the second instar larva *A. quadrimaculatus* is about 0.268 mm. in width. It is less sclerotized and less pigmented than in the third and fourth instars. This instar has the same filtering feeding habit as the first, third and fourth instars.

The labrum

The labrum (Fig. 4, Lr) is composed of the palatum and the labral brushes, as in the advanced instars. The two preclypeal hairs (Fig. 4, PrcH) which arise from the sides of the preclypeus, are comparatively light in colour and slender.

(a) The palatum (Figs. 4 and 8, Pl) bears on its margin the palatal hairs (Fig. 4, PlH) which are six or seven in number as in the third instar. In the fourth instar there are eight palatal hairs. The palatum is connected with the clypeus by means of a bell-shaped, unpigmented, flexible sclerite. It differs, therefore, in shape from the triangular shaped area in the third and the fourth instars.

(b) The labral brushes: Each labral brush (Figs. 4 and 8, LB) is composed of only three groups of hairs, while there are four groups in the third instar and five groups in the fourth instar. The two pairs of frontal hairs (Fig. 4, FH) which have been described in the third and fourth instars are also present in the second instar. The lateral branched pair, however, contains a fewer number of branches. The mesal pair is long, slender and less pigmented than in the third and fourth instars.

The apodemes of the labral brushes: The labral apodemes (Fig. 8, LAp) are shorter, less sclerotized and less pigmented than those of the advanced instars. The anterior process of the labral apodeme (Fig. 8, AAp) is very small and hard to see even by the highest powers of the dissecting microscope. The lateral labral plate (Fig. 8, LLP) is smaller in size, less pigmented and less sclerotized than that of the advanced instars. The transverse bars (Fig. 8, TB) are different in shape from those of the third and fourth instars. They are more or less Z-shaped and do not meet at the meson. They are less sclerotized and less pigmented compared with those of the advanced instars.

The epipharynx

The epipharynx (Fig. 8, Ep) is composed, as in the third and fourth

instars, of the epipharyngeal hairs and the epipharyngeal sclerite. The lateral extremities of the epipharyngeal sclerite (Fig. 8, EpSc) are articulated to the middle of the labral apodemes; instead of its proximal third as in the third and fourth instars. The angle formed between the arms of the epipharyngeal sclerite is smaller than that in the advanced instars. Each arm, however, is dilated twice instead of once as in the case of the third and fourth instars. Most of the epipharyngeal hairs (Fig. 8, EpH) in this instar extend caudad. They are finer, shorter and fewer in number than those of the third and fourth instars. The small fan-shaped group of hairs, located in the angle formed between the epipharyngeal sclerite and the labral apodemes, which has been described in the advanced instars, is less prominent in the second instar.

The mandibles

The mandibles (Figs. 12 and 16) are similar in shape to the mandibles of the third and fourth instars; but they are less sclerotized and smaller in size. The ventral group of dentes (Figs. 12 and 16, VDt) consists of seven dentes, while there are eight in both the third and fourth instars. The most lateral, short, ventral dent is absent in the second instar. The serrated dentes (Figs. 12 and 16, SrDt) are three in number, and similar in shape to those of the advanced instars. The dorsal group of dentes (Fig. 16, DDt) is composed of six dentes; while there are seven in the third instar and ten in the fourth instar. As in the third and fourth instars, the mandible is articulated to the ventral wall of the cranium by the preartis and the postartis (Figs. 12 and 16, PrA and PoA). The setae arising from the lateral region of the mandible are fewer in number than those of the advanced instars. Cephalad of this group there is another small group of five or six short fine hairs arising from one point. The fine short setae arising from the ventral surface which have been described in the advanced instars are absent in the second instar. The lateral bristles (Figs. 12 and 16, LBr) are comparatively shorter and less stout. The mandibular brush (Figs. 12 and 16, MdB) is similar in shape to that of the third and fourth instars but the setae are fewer in number and less stout.

The maxillae

The maxillae (Fig. 20) are smaller in size than those of the third and fourth instars. The setae that border and cloth the cardostipes (Fig. 20, CdSt) are finer and fewer in number than those of the advanced instars. As in the advanced instars, the maxilla is articulated to the ventral wall of the cranium by means of the entoparartis and the exoparartis (Fig. 20, Enp and Exp); and along the caudal margin of the cardostipes. The cleft (Fig. 20, C) is shorter and more blunt than those of the third and fourth instars. The

maxillary spine (Fig. 20, MxSp) is more slender and less pigmented than that of the advanced instars. The maxillary palpus (Fig. 20, MxP) is comparatively short and slender. The sensoria (Fig. 20, S) appear to be six in number instead of five in the third and fourth instars. The tree-shaped branched bristle which arises from the lateral margin of the palpus in the third and fourth instars, is absent in the second instar; thus providing an important taxonomic feature. The lateral branches of the plumose bristle (Fig. 20, MAB) are shorter and fewer in number than those of the third and fourth instars.

The labium

It is composed of four parts as in the advanced instars. The submentum is similar in shape to that of the advanced instars, but smaller and less sclerotized.

The mentum (Fig. 24) is narrower and less sclerotized than that of the advanced instars.

The glossa (Fig. 28) is smaller, less sclerotized and less pigmented than that of the advanced instars. It bears, however, eight blunt teeth-like projections, four on each side as in the third and fourth instars.

The paraglossa (Fig. 32) consists of nine teeth, four on each side of a large disto-central tooth. In few cases the paraglossa is composed of seven teeth, three on each side of a central tooth.

The hypopharynx

The hypopharynx (Fig. 36) is smaller in size and less sclerotized than that of the third and the fourth instars. The transverse ridge (Fig. 36, TR) is short and slender. The salivary duct opening (Fig. 36, SO) is very hard to see. The microspines (Fig. 36, MSp) are very tiny and fewer in number than those of the third and fourth instars. The two lateral lobes (Fig. 36, L) are comparatively small. The hypopharyngeal spines (Fig. 36, HypSp) are also few in number. The lateral arms of the cross-shaped sclerotized area bear five spines (Fig. 36, LSp), three on the left arm and two on the right arm. The movable spines (Fig. 36, MvSp) are six in number, three on each side. In the third instar, the movable spines are seven in number; and in the fourth instar they are eight in number.

IX. THE MOUTH PARTS OF THE FIRST INSTAR LARVA

The head capsule of the first instar larva of *A. quadrimaculatus* is about 0.184 mm. in width. It is comparatively small and light in colour. The head of the first instar is characterized, however, by the egg burster (Fig. 38, EB) which is situated on the frons (Fig. 38, F).

The labrum

The labrum (Fig. 5, Lr) is composed of the palatum and the two labral brushes, as in the advanced instars. The preclypeal hairs (Fig. 5, PrcH) arising from the side of the preclypeus are more slender and shorter than those of the advanced instars.

(a) The palatum (Figs. 5 and 9, Pl) is more or less membranous and smaller than those of the advanced instars. The palatal hairs (Fig. 5, PlH) are six in number. The palatum is attached to the preclypeus by means of the more or less bell-shaped membranous structure, that differs in shape from that of the second as well as those of the third and fourth instars.

(b) The labral brushes (Figs. 5 and 9, LB) are relatively shorter and lighter in colour than those of the advanced instars. Each labral brush is composed of three groups of hairs as in the second instar. However, each of those groups is composed of relatively short hairs, less dense and of finer consistency than those of the advanced instars. The two pairs of frontal hairs (Fig. 5, FH) are short and less rigid. The lateral pair is different in shape than that of the second, third and fourth instars. Each has a very short stalk which does not divide into two stems as in the advanced instars, but branches immediately into several long, flexible and fine setae that lie across the labral brushes when they are in the extended position.

The apodemes of the labral brushes: The labral apodeme is short and very lightly sclerotized. Its anterior process (Fig. 9, AAP) shows as a very minute projection; while the medial and posterior processes (Fig. 9, MAP and PAP) are well developed but less sclerotized than those of the advanced instars. The lateral labral plate (Fig. 9, LLP) is small in size and lightly sclerotized. The transverse bars (Fig. 9, TB) are more or less membranous, lightly pigmented and do not meet each other at the meson.

The egg burster

The egg burster (Fig. 38, EB) is located roughly in the middle of the frons. It is subquadrangular in shape. It is constructed of a membranous and lightly pigmented subquadrangular area, with a dark spine in its center. The egg burster helps to break the chorion of the egg during the hatching process.

The epipharynx

The epipharynx (Fig. 9, Ep) is comparatively small. The epipharyngeal sclerite (Fig. 9, EpSc) is slightly sclerotized and lightly pigmented with its cephalic margin slightly concave giving it the shape of half a circle rather than a V as in the advanced instars. Each arm of the epipharyngeal sclerite is a little dilated at its middle. The epipharyngeal hairs (Fig. 9, EpH) are

relatively short and fewer in number than those of the advanced instars. The small fan-shaped group of hairs located in the angle between the epipharyngeal sclerite and the labral apodemes on each side is present but smaller than those of the older instars.

The mandibles

The mandibles (Figs. 13 and 17) are similar in shape to the mandibles of the older instars, although they are smaller and less sclerotized. The ventral group of dentes (Figs. 13 and 17,VDt) has seven dentes as in the second instar; while they are eight in the third and the fourth instars. The most lateral tooth which is present in the third and fourth instars is absent in this instar as well as in the second instar. The serrated dentes (Figs. 13 and 17,SrDt) are three in number but they are a little shorter and less sclerotized than those of the advanced instars. The dorsal group of dentes (Fig. 17,DDt) is composed of six teeth as in the second instar. As in the advanced instars, the mandible is articulated to the ventral wall of the cranium by means of the preartis and the postartis (Figs. 13 and 17,PrA and PoA) as in the older instars. The lateral margin bears a group of five or six short hairs which extend latero-cephalad. The four lateral bristles (Figs. 13 and 17,LBr) are similar in shape and construction to those of the advanced instars, but they are shorter and more slender. The mandibular brush (Figs. 13 and 17,MdB) consists of fewer and shorter less rigid setae.

The maxillae

The maxillae (Fig. 21) are smaller and less sclerotized than those of the older instars. The setae which cloth and border the cardostipes (Fig. 21, CdSt) are short, fine and widely separated. The maxilla is articulated to the ventral wall of the cranium by means of the entoparartis and the exoparartis (Fig. 21,Enp and Exp) as well as along the entire length of the caudal margin of the cardostipes, as in the older instars. The cleft (Fig. 21,C) at the proximal region of the lateral margin of the cardostipes is short, narrow and sharply pointed, differing from that of the second instar which is blunt. The maxillary spine (Fig. 21,MxSp) is comparatively short and slender. The maxillary palpus (Fig. 21,MxP) is smaller in size and less sclerotized than those of the older instars. There are slight variations in the number of the sensoria (Fig. 21,S). In the majority of cases, they are five, while in a few cases there are six as in the second instar. As in the second instar, but differing from the third and fourth instars, the branched maxillary palpal bristle is absent. The plumose bristle (Fig. 21,MAB) is reduced considerably. Its lateral branches are short, fine and do not exceed five in number.

The labium

The labium is composed of the submentum, mentum and the prementum as in the older instars. The submentum is smaller and less sclerotized than those of the second, third and fourth instars.

The *mentum* (Fig. 25) is more or less membranous and narrower than that of the second instar.

The *glossa* (Fig. 29) is composed, as in the advanced instars, of eight teeth-like projections, four teeth on each side. In rare cases, however, the glossa consists of six teeth, three on each side.

The *paraglossa* (Fig. 33) is smaller, less sclerotized and less pigmented than those of the advanced instars. It consists in the majority of cases, of nine teeth, four on each side of the large disto-central tooth as in the paraglossa of the second instar; while that of the third and fourth instars contains 11 teeth, five on each side of the large disto-central tooth.

The hypopharynx

The hypopharynx (Fig. 37) is smaller and less sclerotized than that of the advanced instars. The transverse ridges (Fig. 37,TR) are shorter than in the second instar. The salivary opening (Fig. 37,SO) is so small and minute that it is hard to see even with the help of the higher magnifications of the compound microscope. The two lateral lobes (Fig. 37,L) are smaller than those of the advanced instars. The microspines found on the sides of the salivary opening in the second, third and fourth instars are obsolete in the first instar. On the mesal line of the area caudad of the transverse ridges are situated two teeth instead of three which were described in the older instars. The hypopharyngeal spines (Fig. 37,HypSp) are comparatively very few and lightly pigmented. The lateral arms of the cross-shaped sclerotized area carry five lateral spines (Fig. 37,LSp) as in the second instar, but they are smaller. The movable spines (Fig. 37,MvSp) are six in number, three on each side as in the second instar. They are slender, blunter and shorter than those of the advanced instars.

X. SUMMARY OF THE IMPORTANT INSTAR DIFFERENCES

Because of the similarity of the various parts of the mouth in the different instars, it would be of great value to point out the most significant differences and trace their development through the first, second, third and fourth instars of this species.

The two pairs of *frontal hairs* of the first instar (Fig. 5,FH) are flexible, slender and relatively short. The lateral pair which arises from the cephalo-lateral region of the frons, is composed of a short stalk each, which

gives rise immediately to fine and relatively short branches. In the second instar, each is composed of a short stalk which divides into two stems and each divides distally into several fine and relatively long branches. In the third and fourth instars, the lateral pair of frontal hairs is similar to that of the second instar but is relatively longer and stouter.

One of the important characteristics of the first instar larva is the presence of the egg burster (Fig. 38,EB) in the middle of the frons (Fig. 38,F).

The labral brush of the first instar (Figs. 5 and 9,LB) is less dense than those of the older instars. It consists of three groups of hairs as in the second instar. In the third instar, the labral brush (Figs. 3 and 7,LB) is composed of four groups of hairs; while that of the fourth instar (Figs. 2 and 6,LB) is composed of five groups.

The transverse bar of the first instar (Fig. 9,TB) is more or less membranous, very lightly pigmented and slightly curved meso-cephalad. The two halves do not meet each other at the meson. In the second instar, the transverse bar (Fig. 8,TB) is slightly pigmented and its two halves do not meet each other at the meson. In the third instar, the transverse bar (Fig. 7,TB) is more pigmented and sclerotized, and its two halves do not meet at the meson also. The two halves of the transverse bar of the fourth instar (Fig. 6,TB) meet each other at the meson. It is heavily pigmented and sclerotized, with a narrow membranous area attached caudad of the heavily pigmented part.

The ventral group of dentes in the mandible of the first instar (Figs. 13 and 17,VDt) consists of seven dentes, as in the second instar (Figs. 12 and 16,VDt). The ventral dentes in the mandibles of the third and fourth instars (Figs. 11, 10, 15 and 14,VDt) are eight in number, due to the development of a short stout tooth laterad of the dentes-bearing area. The dorsal dentes of the first and second instars (Figs. 17 and 16,DDt) are six in number, while those of the third instar (Fig. 15,DDt) are eight and those of the fourth instar (Fig. 14,DDt) are ten.

The maxillary palpus of the first instar (Fig. 21,MxP) is relatively large and lightly pigmented. The palpus of the second instar (Fig. 20,MxP) is larger and more pigmented than that of the first instar. The palpi of the third and fourth instars (Figs. 19 and 18,MxP) are considerably large; and each palpus bears on the proximal end of the distal third of its lateral margin a branched tree-shaped bristle (Figs. 19 and 18,MxPB) which is lighter in colour in the third than in the fourth.

The glossa of the first instar (Fig. 20) is lightly pigmented and is composed of either eight or six blunt teeth-like projections with four or three projections on each side of the mesal line. The proximal pair of teeth, however, is not well developed. The glossae of the second, third and fourth

instars (Figs. 28, 27 and 26) increase gradually in size, sclerotization and pigmentation. Each is composed of eight teeth, four on each side of the mesal line.

The paraglossa of the first instar (Fig. 33) is composed of nine teeth, four on each side of the disto-central tooth. The paraglossa of the second instar (Fig. 32) consists of the same number of teeth, but more pigmented and sclerotized. The paraglossae of the third and fourth instars (Figs. 31 and 30) consist of eleven teeth, five on each side of the disto-central tooth.

The hypopharynx of the first instar (Fig. 37) is small quadrangular in shape and lightly pigmented. There are no microspines in its cephalic area, which are present in the second, third and fourth instars (Figs. 36, 35 and 34, MSp). There is a gradual increase in size, degree of sclerotization, pigmentation and the number of the lateral and movable spines (Figs. 36, 35 and 34, LSp and MvSp) after each moult in the second, third and fourth instars.

XI. KEY TO THE FOUR LARVAL INSTARS OF ANOPHELES QUADRIMACULATUS (SAY) BASED ON THE HEAD STRUCTURES

1. Egg burster in the dorsal aspect of the frons absent.....2
- 1a. Egg burster on the dorsal aspect of the frons present (Fig. 38, EB). Head about 0.184 mm. in width. Lateral pair of frontal hairs (Fig. 5, FH) with short stalk which divides into fine flexible branches. Labral brush (Figs. 5 and 9, LB) with three groups of hairs. Anterior process of labral apodeme (Fig. 9, AAp) minute. Mandible with seven ventral dentes (Figs. 13 and 17, VD_t) and six dorsal dentes (Fig. 17, DD_t). Maxillary palpus (Fig. 21, MxP) bears no branched bristle on its lateral margin. Glossa (Fig. 29) slender with eight or six blunt teeth-like projections, four or three on each side, with the caudal pair poorly developed. Paraglossa (Fig. 33) with nine teeth, four on each side of the disto-central tooth. Hypopharynx (Fig. 37) small with no microspines cephalad. Hypopharyngeal lateral spines (Fig. 37, LSp) five and movable spines (Fig. 37, MvSp) six.....**First instar**
2. Maxillary palpus bears a tree-like branched bristle (Figs. 18 and 19, MxPB) on its lateral margin.....3
- 2a. Maxillary palpus bears no bristle on its lateral margin. Mandible with seven ventral dentes (Figs. 12 and 16, VD_t) and six dorsal dentes (Fig. 16, DD_t). Paraglossa (Fig. 32) with nine teeth, four on each side of a disto-central tooth. Hypopharynx (Fig. 36) large with microspines (Fig. 36, MSp) present cephalad. Hypopharyngeal lateral

- spines (Fig. 36,LSp) five, and movable spines (Fig. 36,MvSp) six. Head about 0.268 mm. in width.....**Second instar**
3. Mandible with less than ten dorsal dentes (Fig. 15, DDt) and eight ventral dentes (Fig. 11 and 15,VDt). Labral brush (Figs. 3 and 7,LB) with four groups of hairs. Branched maxillary palpal bristle (Fig. 19,MxPB) with few lightly coloured branches. Paraglossa (Fig. 31) with 11 teeth, five on each side of the disto-central tooth. Paraglossa sometimes with nine teeth. Hypopharynx (Fig. 35) large, with six lateral spines (Fig. 35,LSp) and seven or eight movable spines (Fig. 35,MvSp). Head about 0.445 mm. in width.....**Third instar**
- 3a. Mandible with ten dorsal dentes (Fig. 14,DDt) and eight ventral dentes (Figs. 10 and 14,VDt). Labral brush (Figs. 2 and 6,LB) with five groups of hairs. Branched maxillary palpal bristle (Fig. 18,MxPB) large and with numerous dark-coloured branches. Paraglossa (Fig. 30) with 11 teeth, five on each side of the disto-central tooth. Hypopharynx (Fig. 34) large, highly sclerotized and heavily pigmented. Hypopharyngeal lateral spines (Fig. 34,LSp) seven, and movable spines (Fig. 34,MvSp) eight. Head about 0.753 mm. in width.....**Fourth instar**

XII. SELECTED REFERENCES

- Abdel-Malek, A. (1948) : Plant hormones (Auxins) as a factor in the hatching of *Aedes trivittatus* (Coquillett) eggs (*Ann. Ent. Soc. Amer.*, XLI, pp. 52-57).
- Becker, E. (1938) : The mouth apparatus of *Anopheles* larva and its movements in feeding upon organisms of the surface film water (*Zoologist Jour.*, XVII (3), pp. 427-440).
- Boyd, M. F. (1926) : A note on the rearing of anopheline larvae (*Bull. Ent. Res.*, XVI, p. 308).
- Burton, G. J. (1953) : Some techniques for mounting mosquito eggs, larvae, pupae and adults on slides (*Mosquito News*, XIII, pp. 7-15).
- Cook, Edwin F. (1944a) : The morphology of the larval heads of certain Culicidae (Diptera) (*Microentomology*, IX (2), pp. 38-68).
- Cook, Edwin F. (1944b) : On the morphology of the larval head of a species of *Chironomus* (Diptera : Chironomidae) (*Microentomology*, IX (2), pp. 69-72).
- Comstock, J. H., and C. Kochi (1902) : The skeleton of the head of insects (*Amer. Nat.*, XXXVI, pp. 13-45).
- Comstock, J. H. (1949) : An introduction to Entomology (Ninth Ed., Comstock publishing Co.).
- Crampton, G. C. (1921) : The sclerites of the head and the mouth-

- parts of certain immature and adult insects (*Ann. Ent. Soc. Amer.*, XIV, pp. 65-108).
- Dodge, H. R. (1945) : Notes on the morphology of mosquito larvae (*Ann. Ent. Soc. Amer.*, XXXVIII (2), pp. 163-167).
- Dyar, H. G. (1902) : Illustrations of the larvae of North American Culicidae (*Journ. N.-Y. Ent. Soc.*, X, pp. 194-201).
- Farnsworth, Marjorie W. (1947) : The morphology and musculature of the larval head of *Anopheles quadrimaculatus* Say (*Ann. Ent. Soc. Amer.*, XLI (1), pp. 137-151).
- Foot, Richard H. (1952) : The larval morphology and chaetotaxy of the *Culex* subgenus *Melanoconion* (Diptera, Culicidae) (*Ann. Ent. Soc. Amer.*, XLV (3), pp. 445-472).
- Howard, L. O., Dyar, H. G., and Knab (1912) : The mosquitoes of North and Central America and the West Indies (*Carnegie Inst. (Wash.)*, publication No. 159, 150 pls.).
- Imms, A. D. (1907) : On the larval and pupal stages of *Anopheles maculipennis*, Meigen (*Jour. Hyg.*, VII (2), pp. 291-318).
- Imms, A. D. (1908) : On the larval and pupal stages of *Anopheles maculipennis*, Meigen (*Parasit.*, 1 (9), pp. 103-133).
- Johannsen, O. A. (1903) : Aquatic nematoceros Diptera, I (*N.-Y. State Mus. Bull.*, LXVIII, pp. 328-448).
- Johannson, O. A. (1905) : Aquatic nematoceros Diptera, II. (*N.-Y. State Mus. Bull.*, LXXXVI, pp. 75-327).
- MacGillivray, A. D. (1923) : External insect-anatomy (Scarab Company, Urbana, Illinois, 388 pages).
- Meinert, F. (1886) : De eucephale mygglarver (*Det Kongelige Danske Videnskabernes Selskabs Skrifter. Sjette Raekke. Naturvidenskabelig og Mathematisk Afdeling.*, VI (3), pp. 373-493).
- Miall, L. C., and A. R. Hammond, (1900) : The structure and life-history of the harlequin fly (*Chironomus*) (Oxford, Clarendon press, 196 pages).
- Nuttall, G. H. F., and Shipley, A. E. (1901) : The structure and biology of *Anopheles*. The egg and larva (*Jour. Hyg.*, I (1), pp. 45-77).
- Nuttall, G. H. F., and Shipley, A. E. (1903) : The structure and biology of *Anopheles* (*Anopheles maculipennis* Meigen), Part II (*Jour. Hyg.*, III, pp. 111-215).
- Pratt, H. D. (1943) : The identification of the first stage larvae of Puerto Rican *Anopheles* (*U.S. Publ. H. Rpts.*, LVIII (2), pp. 1715-1718).
- Puri, I. M. (1928) : The relationship of certain morphological characters of anopheline larvae to the classification of Indian anopheline mosquitoes (*Ind. Jour. Med. Res.*, XVI, pp. 519-528).
- Puri, I. M. (1931) : The larvae of anopheline mosquitoes with full des-

- cription of those of the Indian species (*Ind. Jour. Med. Res.*, Mem. No. 21, pp. 1-227).
- Raschke, E. W. (1887) : Die larve von *Culex nemorosus*. Ein Beitrag zur Kenntniss der Insekten-anatomie und histologie (*Arch. f. naturgesch.*, LIII, pp. 133-163).
- Root, F. M. (1932) : The larvae of American *Anopheles* mosquitoes in relation to classification and identification. (*Amer. Jour. Hyg.*, II, pp. 379-393).
- Ross, H. H. (1947) : The mosquitoes of Illinois (*Bull. Ill. Nat. Hist. Survey*, XXIV, pp. 1-96).
- Salem, H. H. (1931) : Some observations on the structure of the mouth-parts of the fourth stage larva of *Aedes (Stegomyia) fasciata* (Fab.) (*Ann. Trop. Med. parasit.*, XXV, pp. 393-419).
- Schrammer, F. (1949) : Morphologische und funktionelle Analyse der Mundteile und des Pharynx der Larve von *Anopheles maculipennis* Meig. (*Caterr. Zool. Zeitschr.*, II, pp. 173-222).
- Snodgrass, R. E. (1935) : Principles of insect morphology (McGraw-Hill Book Co., N.-Y., 327 pages).
- Torre-Bueno, J. R. (1950) : A glossary of entomology (2nd. ed., *Brooklyn Ent. Soc.*, Brooklyn, N.-Y., 336 pages).
- Wesché, W. (1910) : On the larval and pupal stages of West African Culicidae (*Bull. Ent. Res.*, I (1), pp. 7-50).
- Wheeler, W. M. (1893) : A contribution to insect embryology (*Jour. Morph.*, VIII, pp. 1-160).
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The egg-pods of some Egyptian grasshoppers and the preference of females for soils of different moisture contents



[Orthoptera : Acrididae]

(with 6 Figures and 6 Tables)

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INTRODUCTION

All species of Acrididae occurring in our district deposit their egg-pods in the soil. Under laboratory conditions and at optimum temperatures and moisture, most of the species are sexually mature and females are ready to oviposit at any time of the year. In nature, such conditions are hardly fulfilled, and there are few generations a year in most species: the adults of *Aiolopus savignyi* (Krauss) and *Euprepocnemis plorans* (Charp.) are not present during winter; the former hibernates in the egg-stage while the latter goes into a state of egg-diapause till the following spring, and *Anacridium aegyptium* (L.) has only one generation.

The number of eggs in the egg-pods, though not fixed, is related to the number of ovarioles. Phipps (1949) and Waloff (1950) have shown that in *Omocestus viridulus* (L.), *Chorthippus parallelus* (Zett.) and *Gomphocerippus rufus* (L.) the majority of females have ten ovarioles, 5 in each ovary, and the usual number of eggs is ten. In *Myrmeleottetix maculatus* (Thunb.) the usual number of ovarioles and eggs is six, and in *Chorthippus bicolor* (Charp.) fourteen. The change in the number of eggs, which is of a common occurrence among Acrididae, consists in the appearance of relatively undeveloped ovarioles which do not produce eggs of the normal size. The occurrence of such "small" ovarioles, which seems to be seasonal, results in that the egg-pods of any species do not usually have the same number of eggs, and that the number of eggs produced at one time is sometimes less than the total number of ovarioles (Phipps, 1949). There is a great variation in the number

of ovarioles and eggs in our species. Undeveloped ovarioles are always present, but the occurrence of corpora lutea at their bases shows that they have produced eggs and emptied them in the oviduct but development proceeds afterwards at a slower rate.

The observations described in the present paper form one of the necessary steps in the study of the ecology of grasshoppers. In Egypt, there are several species of Acrididae; but only seven, *Aiolopus thalassinus* (F.), *Aiolopus savignyi* (Krauss), *Acrotylus insubricus* (Scop.), *Calephorus venustus* (Walk.), *Chrotogonus lugubris* (Blanch.), *Pyrgomorpha conica* (Cl.) and *Euprepocnemis plorans* (Charp.) are generally abundant in our district. It is the object of this paper to describe their egg-pods and to study the preference of females for soil moisture.

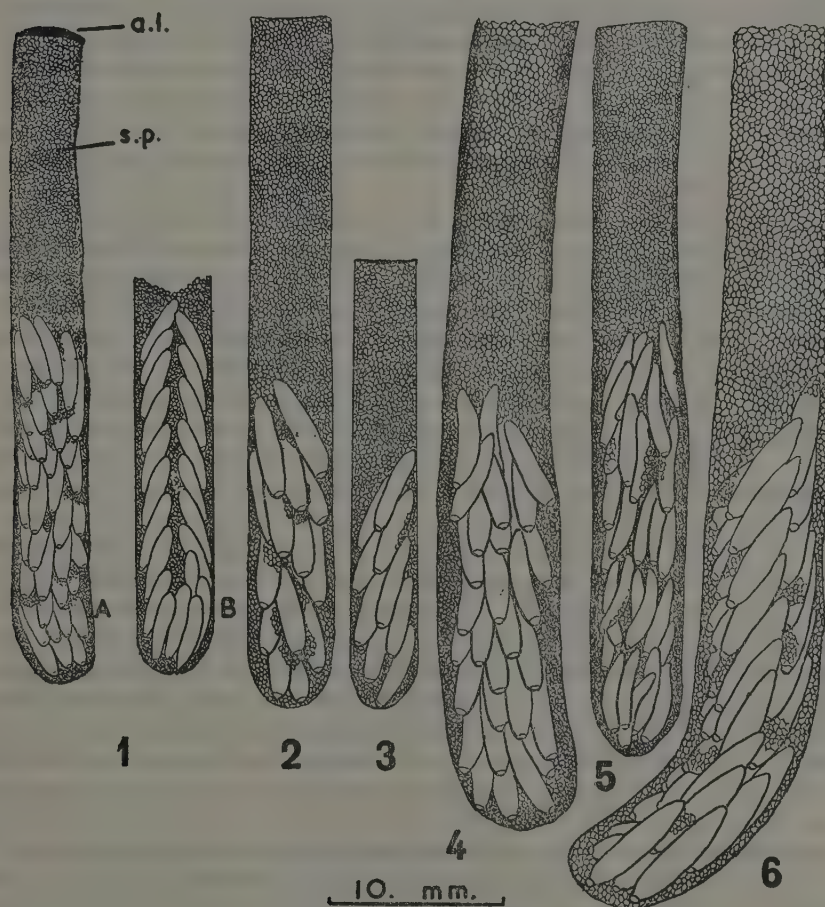
DESCRIPTION OF EGG-PODS

The egg-pods of the above mentioned species are generally composed of two distinguishable parts : a spongy pad which occupies the distal part and a basal portion which contains the eggs. In *Aiolopus thalassinus* and *A. savignyi* (Fig. 1), the pod is generally cylindrical, straight, but sometimes slightly bent. It is broader at the basal part and narrowed towards the apex. There is an easily detachable thin apical lid; this is made of a more compact secretion of the accessory glands. The apical lid is often covered with adhering soil particles, but it is left bare when oviposition occurs in sodden soil. The spongy pad is about 1.7 cm. long, white or light buff and finely meshed. It is more compact at the outer wall of the pod and at its base. The spongy secretion surrounds and extends into the basal part containing the eggs. It forms lamellae between the eggs and firmly holds them together. The basal part of the pod is about 2 cm. long and 4.3 mm. wide, its average length is 3.7 cm.

The egg-chorion is thin and pale brown, and darker at the micropylar end. The eggs are mostly arranged in four rows and at an angle of about 45 degrees to the long axis of the pod. When newly laid, the eggs is about 3.6 mm. long, and 0.8 mm. wide. The eggs start to absorb water from the soil after about four days from oviposition; by this time the hydropyle, the water absorbing organ, is secreted. They slightly increase in length, but markedly increase in width. The outer wall of the basal part of the pod eventually cracks, and after about ten days (at 25°C.) the eggs are no longer held together by the intervening spongy secretion, they lie quite freely in the egg-pod.

In *Aiolopus thalassinus* the number of eggs in the egg-pods varied from 8 to 34. The average number was 21.7 eggs in the 63 egg-pods which were examined. In May 1952, 14 females were dissected, the mean number of ovarioles was 42.2, 36.6 for the fully developed and 5.6 for the "small" ones.

65 pods of *Aiolopus savignyi* were examined, the number of eggs ranged between 16 and 43, with an average of 28. In July 1952, 3 females were dissected, the mean number of ovarioles was 49.7, 25 for the fully developed and 24.7 for the "small" ones. In both species *coprora lutea* are yellowish green.



- Fig. 1 : Egg-pod of *Aiolopus thalassinus* and *Aiolopus savignyi* (A, front view ; B, the arrangement of the eggs at the opposite side (a.l., apical lid ; s.p., spongy pad).
 — Fig. 2 : Egg-pod of *Acrotylus insubricus*. — Fig. 3 : Egg-pod of *Calephorus venustus*.
 — Fig. 4 : Egg-pod of *Chrotogonus lugubris*. — Fig. 5 : Egg-pod of *Pyrgomorpha conica*.
 — Fig. 6 : Egg-pod of *Euprepocnemis plorans*.

In *Acrotylus insubricus* (Fig. 2) the pod is always straight. The basal part of the pod is about 1.8 cm. long, and 4.7 mm. wide. The average length of the pod is 3.9 cm., but pods of 6.5 cm. were encountered. There is no apical lid, and the opening is protected by a thin film of hardened secretion. The mesh of the spongy pad is slightly larger than that of *Aiolopus thalassinus*. It surrounds the basal part and extends between the eggs. When newly laid, the eggs are lightly glued together, and are arranged in 3-4 longitudinal rows and slightly sloping towards one side of the pod. The egg is 5 mm. long and 0.8-1 mm. wide. The number of eggs in the egg-pods varied from 7 to 24; 81 pods were examined, the average number was 14.8 eggs. In May 1952, 14 females were dissected, the mean number of ovarioles was 26.8, 22.6 for the fully developed and 4.2 for the "small" ones. *Corpora lutea* are red.

In *Calephorus venustus* (Fig. 3), the pod is about 2.5 cm. long and the spongy pad is about 1.4 cm., while the basal part is about 3.9 mm. wide. The foamy secretion is very soft and finely meshed; it surrounds and penetrates between the eggs, forming lamellae which hold them together. There is a weakly formed apical lid. The eggs are arranged in three conspicuous longitudinal rows, and lie at an angle of about 45 degrees to the long axis. The egg is 4 mm. long and 0.7 mm. wide. The number of eggs in the egg-pods varies from 6 to 15. 9 pods were examined, the average number was 11.1. In February 1953, 4 females were dissected, the mean number of ovarioles was 18, 14 for the fully developed and 4 for the "small" ovarioles. *Corpora lutea* are red.

In *Chrotogonus lugubris* (Fig. 4), the pod is fairly long and stout. The average length is 4.6 cm., and the mean width of the basal part is 6.9 mm. Pods of 6.7 cm. were encountered. The average length of the basal part is 2.5 cm. There is no apical lid and the apex is bare or slightly covered with soil particles. The spongy pad is light buff and shiny. The mesh is large and the foamy secretion does not penetrate between the eggs. It forms a thick, tough outer covering. The contours of the eggs are not clearly visible externally. The eggs lie freely, more or less vertically and are arranged in 4-5 rows. The egg is 4.5 mm. long and 0.9 mm. wide. The chorion is tough and dirty brown. The micropylar cone is short and the micropyles form a dark brown ring above it. The number of eggs in the egg-pods varies from 15 to 58. 55 pods were examined and the average number was 36 eggs. In June 1952, 9 females were dissected and the mean number of ovarioles was 56.1, 50.9 for the fully developed and 5.2 for the "small" ones. *Corpora lutea* are red and conspicuous.

In *Pyrgomorpha conica* (Fig. 5) the pod is cylindrical, about 4.2 cm. long and 4-5 mm. wide. The spongy mass forms a pad 1.7 cm. high above the eggs. There is no apical lid, but the apex is protected by a thin layer of the

accessory glands' secretion. The spongy substance is whitish and fairly coarsely meshed. It surrounds and extends between the eggs and forms a thick outer covering. The eggs lie freely between the lamellae of the spongy secretion and are not glued together. They tend to be arranged in 4-6 layers, each of which comprises several eggs sloping towards the walls. The eggs are slightly curved and slender, 3.5 mm. long and 0.7 mm. wide. The egg-chorion is yellowish and the micropyles form a brownish ring round the posterior end. The number of eggs in the egg-pods varies from 16 to 77. Six pods were examined and the average number was 42.2 eggs. In August 1954, 2 females were dissected and the mean number of ovarioles was 60, 34.5 for the fully developed and 25.5 for the "small" ones. The ovaries in many others were found to be either immature or exhausted. Corpora lutea are light red or orange.

In *Euprepocnemis plorans* (Fig. 6), the pod is cylindrical and the basal part is occasionally bent. It is 5-6 cm. long, and 6-7 mm. wide at the basal part. The spongy pad is dark brown and very coarsely meshed. It has a tough texture and the contours of the eggs are not visible externally. It forms a dense pad 2-3 cm. high above the egg-mass. There is no apical lid and the apex of the spongy pad is always bare. The spongy secretion extends between the eggs and forms several cavities in which the eggs lie freely. They are arranged in six longitudinal rows, in four of them the eggs tend to be sloping towards the walls, in the fifth and the sixth the eggs lie at one side of the pod and are arranged as shown in Fig. 1B. The egg is 5-6 mm. long and 0.9-1.7 mm. wide. The chorion is tough and generally dark brown, but sometimes reddish-brown or black.

The number of eggs in the egg-pods varied from 19 to 78. 106 pods were examined and the average number was 49.1. In August 1952, 5 females were dissected and the mean number of ovarioles was 87. In four females there were no "small" ovarioles, but in the fifth there were 9 and 8 "small" ovarioles in the right and left ovary, respectively. It is likely that the four females were about to lay their first pod as corpora lutea were not present. In the other female these red-coloured structures were observed in the fully developed as well as in the "small" ovarioles.

THE PREFERENCE OF FEMALES FOR SOILS OF DIFFERENT MOISTURE CONTENTS

Grasshoppers differ in their response to soil moisture. Soil irrigation, especially after a prolonged period of drought, does not greatly influence the climate above the surface of the soil. On newly irrigated fields, the increase of population as a result of immigration may be a positive response to better conditions for egg-laying. Egg-pods cannot be deposited in dry soil, but oviposi-

tion only occurs when soil contains a certain amount of moisture.

In Egypt, when winter crops are cleared, in May or June, a certain period elapses before the land is ready for the cultivation of the summer crops. During such resting period, which may extend to several months, the land loses its water but the atmosphere above it remains generally the same as it is elsewhere. On fallow land, the daily air temperature ranges between 20 and 40°C., and the relative humidity between 30 and 92%. When fallow land is irrigated, weather conditions near the surface remain generally the same. But there may be slight drop in the maximum temperature, one or one and half degrees, and the maximum relative humidity may go up to 100%.

On dry fallow land *Aiolopus thalassinus* was nearly absent, *Aiolopus savignyi* though found on dry soil, seemed to favour moist soil as it increased in number on newly irrigated fields. *Chrotogonus lugubris* had a higher population density on dry fallow land than on irrigated fields, and *Acrotylus insubricus* was found to be indifferent to soil moisture. A study of the preference of each species of grasshopper for soil moisture was, therefore, undertaken under laboratory conditions. Some seven species of grasshoppers are generally found on the Faculty's farm, but only five were chosen for this study: *Euprepocnemis plorans*, *Aiolopus savignyi*, *Aiolopus thalassinus*, *Chrotogonus lugubris* and *Acrotylus insubricus*.

In the experimental cages, female grasshoppers ready to oviposit were observed moving about with a protracted abdomen, opening and closing the valves of the ovipositor and feeling the surface upon which they walked with their antennae and palps. Now and then they stopped, arched their abdomens and tried to probe the floor of their cages. Using their ovipositors, they made holes in any wet piece of cotton wool or cardboard. When wet soil was offered, it was observed that digging was not always followed by egg-laying. A female might bore several holes of different depths before being ready to lay her eggs. This was also observed by Fedorov (1927) in *Anacridium aegyptium* (L.), and by Kennedy (1949) in *Locusta migratoria migratorioides* (R. and F.).

METHOD

Adult grasshoppers were collected in the field and kept in the laboratory in cages nearly similar to those used by Faure (1932). The cage was 40×50 cm. at the base, and 40 cm. high. The sides and top were of wire-netting, and there was a front door which was 40×40 cm. The floor could be separated from the body of the cage and had 20 holes in which 20 egg-tins (each 8 cm. long by 5 cm. diameter) were placed. The tops of the egg-tins were flush with the wooden floor. The tins were filled with soil of different

moisture contents, and in the experiments there were either five treatments and four replicates or four treatments and five replicates.

Light loamy soil was used throughout this study. It was brought from the farm, passed through a sieve the holes of which were 1 mm. wide, and kept for 24 hours in a drying oven running at 110°C. When an experiment started, all tins were first filled with moist soil, and drying was carried out in the sun for a varying length of time. The moisture content in such tins was considered to be evenly distributed in the soil, although there was a slight increase in the bottom layer.

In an experiment of five treatments, egg-tins were prepared on five successive days. On the first day, four tins and two weighed 150 ml. beakers were filled with 160 grams of oven-dry soil and tapped a certain number of times so that the soil particles would be uniformly arranged. The different arrangements of soil particles were found to result in the soil holding different amounts of water. 70 ml. of distilled water was then added to every tin and beaker; this filled all the air spaces between the particles of the soil and no water remained on the surface. The moisture content in such soil was 43.7% (weight/weight). These tins and beakers were placed in the sun. On each of the next three days four more tins and two more weighed beakers were prepared and dried in the same way. On the fifth day, all tins and beakers were brought in the laboratory and four more tins and two more weighed beakers were similarly prepared. Those which had been prepared the first day were the driest and those prepared the fifth day the wettest. The beakers of every treatment were then weighed and their moisture contents noted. The twenty tins were placed at random in the floor of the experimental cage and a certain number of grasshoppers were freed in. The weighed beakers were placed in another cage which contained no grasshoppers; they were weighed again at the end of the experiment and thus the moisture content of every treatment could be estimated. Every experiment lasted for 24 hours during which period room temperature ranged between 30 and 36°C. When an experiment, ended, the tins were taken out and examined.

EXPERIMENTS WITH *EUPREPOCNEMIS FLORANS*

Two experiments were carried out. The first one had four treatments and five replicates, and the second one five treatments and four replicates. 136 females + 183 males and 128 females + 158 males were present in the cage in the first and second experiment, respectively. The moisture contents of the different treatments are shown in Table I, and the results in Tables II and III.

TABLE I

Euprepocnemis plorans :
moisture contents of different treatments

TREATMENTS	MOISTURE PERCENTAGE AT THE BEGINNING OF		MOISTURE PERCENTAGE AT THE END OF		MEAN
	FIRST EXPERIMENT	SECOND EXPERIMENT	FIRST EXPERIMENT	SECOND EXPERIMENT	
A	43.7	43.7	41.1	40.3	42.8
B	34.5	34.2	32.3	31.3	33.1
C	24.9	25.5	23.0	23.2	24.2
D	21.1	20.1	19.5	18.8	19.9
E	—	17.7	—	16.1	16.6

From the results of the first experiment it can be observed that difference between treatments is significant, while difference between egg-tins (replicates) is not significant. Treatment A, which had the highest mean moisture content, 42.8%, received the least number of pods, while treatments B and C, where the mean moisture content was 33.1 and 24.2%, respectively, received the highest number of pods. Treatment D (19.9% moisture) though received 10 pods, the difference between it and treatment B or C is not significant ($F = 4.3$, from Table = 4.8).

TABLE II

Euprepocnemis plorans :
result of first experiment, number of egg-pods in soils of different treatments

TREATMENTS	NUMBER OF PODS IN EACH OF FIVE EGG-TINS					SUM
	1	2	3	4	5	
A	2	1	1	—	—	4
B	5	4	4	9	2	24
C	5	4	6	3	6	24
D	1	—	1	2	6	10
SUM	13	9	12	14	14	62

F obtained for treatments = 4.5; from Table at 0.05 = 3.5

F obtained for replicates = 0.24; from Table at 0.05 = 3.5

In the second experiment, the difference between treatments is also significant, while the difference between egg-tins (replicates) is not significant. Treatment C (24.2% moisture) received the highest number of pods and the difference between it and treatment B, D and E is statistically significant. But there is no significant difference between treatment C and A ($F = 3.4$).

It can be observed that *Euprepocnemis plorans*, though preferred for egg-laying soil which contained 24.2% moisture, could not differentiate between soils which contained a wide range of moisture, 42.8 to 19.9%. The moist soil (42.8% moisture) was nearly avoided in the first experiment, but although it received a lower number of egg-pods in the second experiment it was as attractive as the preferred soil of treatment C. The difference between them was not significant. The dry soil of treatment E (16.6% moisture) was also laid in but it was not preferred when more moist soil was available.

TABLE III

Euprepocnemis plorans :*result of second experiment, number of egg-pods in soils of different treatments*

TREAT- MENTS	NUMBER OF PODS IN EACH OF FOUR EGG-TINS				SUM
	1	2	3	4	
A	4	4	2	3	13
B	2	2	4	2	10
C	5	5	4	4	18
D	3	—	—	—	3
E	2	—	—	2	4
SUM	16	11	10	11	48

F. obtained for treatments = 8.10; from Table at 0.05 = 3.3

F. obtained for replicates = 1.34; from Table at 0.05 = 3.5

TABLE IV

Euprepocnemis plorans :*number of empty holes of different depths, and total number of diggings in soils of different moisture contents.*

TREAT- MENTS	FIRST EXPERIMENT			SECOND EXPERIMENT		
	NUMBER OF EMPTY HOLES	NUMBER OF PODS	TOTAL DIGGINGS	NUMBER OF EMPTY HOLES	NUMBER OF PODS	TOTAL DIGGINGS
A	17	4	21	11	13	24
B	25	24	49	4	10	14
C	6	24	30	7	18	25
D	13	10	23	—	3	3
E	—	—	—	1	4	5

Table IV shows the total number of diggings in soils of different moisture contents. In the first experiment, treatment B received the highest number of diggings, but that of treatment A approximated that of D. This shows that females could not differentiate between these two treatments. In the second experiment there was nearly no difference between the number of

diggings in treatment C and A, but the dry end of the experiment received a much lower number of diggings.

EXPERIMENTS WITH *AIOLOPUS SAVIGNYI*, *AIOLOPUS THALASSINUS*, *ACROTYLUS INSUBRICUS* AND *CHROTOGONUS LUGUBRIS*

Experiments with these species were carried out in four different cages at the same time. Experiments were repeated twice, except with *Acrotylus insubricus* they were repeated three times. Table V shows the mean moisture content of the different treatments and the number of pods laid by the different species.

TABLE V

Aiolopus savignyi, *Aiolopus thalassinus*, *Acrotylus insubricus*,
and *Chrotogonus lugubris* : number of egg-pods laid in soils of different
moisture contents.

TREATMENTS	PERCENTAGE MEAN MOISTURE CONTENT	AIOLOPUS SAVIGNYI (a)	AIOLOPUS THALASSINUS (b)	ACROTYLUS INSUBRICUS (c)	CHROTOGONUS LUGUBRIS (d)
A	42.5	36	23	4	—
B	33.7	20	15	10	8
C	26.2	8	12	17	5
D	20.4	—	6	14	2
E	16.4	1	1	9	2
F obtained for treatment		22.4	4.6	2.3	2.7
F from Table at 0.05			3.3		

(a) Results of two experiments: There were 46 ♀♀ + 12 ♂♂ in the first cage, and 38 ♀♀ + 13 ♂♂ in the second.

(b) Results of two experiments: There were 63 ♀♀ + 17 ♂♂ in the first cage, and 65 ♀♀ + 21 ♂♂ in the second.

(c) Results of three experiments: There were 54 ♀♀ + 20 ♂♂ in the first cage, 58 ♀♀ + 25 ♂♂ in the second, and 50 ♀♀ + 27 ♂♂ in the third cage.

(d) Results of two experiments: There were 113 ♀♀ + 60 ♂♂ in the first cage, and 195 ♀♀ + 82 ♂♂ in the second.

It can be observed that the difference between treatments is significant except with *Acrotylus* and *Chrotogonus*. *Aiolopus savignyi* and *Aiolopus thalassinus* laid the highest number of pods in the moist soil whereas it was rejected by *Chrotogonus* and received the least number of pods in *Acrotylus*. Moreover, in *Chrotogonus* and *Acrotylus* the difference between treatments was not significant even when the total number of diggings (egg-pods + empty holes) was considered. But females had always a tendency to dig more in soil of treatment C than in that of other treatments.

FIELD OBSERVATIONS

In the field, an attempt was undertaken to compare the number of grasshoppers on dry fallow and newly irrigated uncultivated land. In August and September 1952, observations were carried out in an area of about 17 acres which was left fallow after the winter crops. Three trained boys were employed, each starting from the centre made three separate catches, each of 15 minutes. Boys were walking in different directions and when the time for every catch ended they returned to the centre and catches were analysed on the spot as insects were set free from the collecting jars. Collecting was also carried out along streams where grass was abundant and land moist. When the observation area was irrigated and water absorbed, collecting was again carried out.

The incidence of grasshoppers and their relative abundance on fallow, irrigated land and along streams are shown in Table VI. It can be observed that in late summer or early autumn only four species of grasshoppers were encountered on the observation area. But there was a considerable increase in the number of grasshoppers when fallow land was irrigated. In the nine catches there were 84 and 224 insects on fallow and irrigated land, respectively. The population on irrigated land was 2.7 times that on fallow. The increase was mostly due to the immigration of *Aiolopus savignyi* and *Aiolopus thalassinus* from the adjoining cultivated fields.

TABLE VI

Percentage of grasshoppers found on fallow, irrigated land, and along streams.

SPECIES	FALLOW	IRRIGATED LAND	ALONG STREAMS
<i>Aiolopus savignyi</i>	88.1	89.4	72.3
<i>Chrotogonus lugubris</i>	7.1	3.1	5.6
<i>Aiolopus thalassinus</i>	2.4	7.1	21.7
<i>Pyrgomorpha conica</i>	2.4	0.4	0.14
TOTAL	100.0	100.0	100.0

Aiolopus savignyi was always the most abundant, but the number caught on fallow was nearly one third that caught on irrigated land. In nine catches the number of adults and hoppers was 74 and 201 individuals, respectively. *Aiolopus thalassinus* and *Pyrgomorpha* were almost absent on fallow, only two individuals of each were caught. But on irrigated land 16 individuals of the former and only one of the latter were caught. *Chrotogonus lugubris* had a higher density on fallow than on irrigated field; the number caught was 7.1 and 3.1% of the total catch respectively.

Along streams 448 insects were caught : 324 (72.3%) of *Aiolopus savignyi*,

97 (21.7%) of *Aiolopus thalassinus*, 25 (5.6%) of *Chrotogonus lugubris*, and 2 (0.4%) of *Pyrgomorpha conica*. It can be observed that *Aiolopus thalassinus* was still the most abundant, the number of *Aiolopus thalassinus* was considerably higher than what was found on fallow and irrigated land, *Chrotogonus lugubris* was not frequent, and *Pyrgomorpha conica* was rare.

These field observations are in accordance with the results of the egg-laying experiments. *Aiolopus savignyi* and *thalassinus* frequent the moist soil for most probably, egg-laying purpose. But *Chrotogonus lugubris* seems to be a species of great plasticity having no definite preference for a particular habitat. Its indifference to soil moisture indicates that eggs may have a great ability to resist desiccation.

SUMMARY

The egg-pods of seven species of Egyptian Acrididae are described.

Experiments were carried out to study the preference of each species for definite range of soil moisture. In *Aiolopus savignyi* and *A. thalassinus* the greatest number of egg-pods were laid in the moist soil. In *Euprepocnemis plorans*, females preferred for egg-laying a drier type of soil. But *Acrotylus insubricus* and *Chrotogonus lugubris* do not seem to have any definite preference for any degree of soil moisture. Egg-pods were indiscriminately deposited in soils of different moisture contents.

The relative abundance of grasshoppers in three observation areas (fallow, irrigated land and along streams), was studied. The results obtained, are in accordance with the egg-laying experiments.

REFERENCES

- F a u r e , J.C. (1932) : The phases of locusts in South Africa (*Bull. ent. Res.*, XXIII, pp. 293-424, 25 pls., 1 map).
- F e d o r o v , S.M. (1927) : Studies in the copulation and oviposition of *Anacridium aegyptium* (Orthoptera, Acrididae) (*Trans. ent. Soc. Lond.*, LXXV, pp. 53-61).
- J o y c e , R.J.V. (1952) : The ecology of grasshoppers in East Central Sudan (*Anti-Locust Bulletin*, No. 11, 99 pages).
- K e n n e d y , J.S. (1949) : A preliminary analysis of oviposition behaviour by *Locusta* (Orthoptera, Acrididae) in relation to moisture (*Proc. R. ent. Soc. Lond.* (A), XXIV, pp. 83-89).
- P h i p p s , John (1949) : The structure and maturation of the ovaries in British Acrididae (Orthoptera) (*Trans. R. ent. Soc. Lond.*, C, pp. 233-247).
- R i c h a r d , O.W. (1953) : The study of the numbers of the Red Locust *Nomadacris septemfasciata* (Serville) (*Anti-Locust Bulletin*, No. 15, 30 pages).
- W a l o f f , N. (1950) : The egg-pods of British short-horned grasshoppers (Acrididae) (*Proc. R. ent. Soc. Lond.* (A), XXV, pp. 115-126).

Zur Systematik von *Sehirus dubius* Scop.



[Hemiptera-Heteroptera : Cydnidae]

(mit 26 Abbildungen)

von EDUARD WAGNER, Hamburg

Der systematische Wert der Formen *Sehirus* (*Canthophorus*) *dubius* Scop., *S. melanopterus* H.S. und *S. impressus* Horv. wird von den Autoren der letzten 40 Jahre recht unterschiedlich beurteilt. Aus diesem Grunde habe ich einmal umfangreicheres Material dieser Formen untersucht und dabei auch den Bau der Genitalien herangezogen. Das Ergebnis dieser Untersuchungen war, dass sich die 3 Formen durch äussere Merkmale kaum trennen lassen, dagegen der Bau der Genitalien ein absolut sicheres Kriterium fuer ihre Trennung darstellt. Daneben zeigte sich, dass auch der in Ostasien lebende *S. niveimarginatus* Scott zu unserer Gruppe gehoert. In einer Sendung des Naturhistorischen Museums Wien fand ich dabei auch 3 Tiere von *S. impressus* Horv., die ohne Zweifel das authentische Material der Art darstellen. Es waren 1 ♂ und 2 ♀♀. Alle 3 trugen einen Zettel mit der Aufschrift : "Plason - 1874 - Heilig Blut" und das 1. Tier darunter einen 2. Zettel mit der Aufschrift "Type", das 2. Tier einen solchen mit "Horv. videt" und das 3. Tier einen solchen mit "*S. impressus* Horv.". Da es in der Originalbeschreibung Horv. a t h s (*Term. Fueset.*, IV : 184) heisst : "In Carinthia ad Heiligenblut lectus et a Dom. A. Rogenhofer benigne communicatus (Mus. Wien)", haben wir hier, wie mir Herr Dr. M. Beier vom Naturhistorischen Museum Wien bestaetigte, die verloren geglaubten Typen von *S. impressus* vor uns.

Die Trennung der 3 Formen ist beim ♀ schon ohne eine Zergliederung des Tieres moeglich (Fig. 1). Bei *S. dubius* (oben) sind die Segmente zusammengekommen 1.6-1.7× so breit wie in der Mitte hoch. Die Lappen des 7. Sternits sind etwa so breit wie hoch, ihr Hinterrand liegt etwa in der Mitte des gesamtem Komplexes. Das (am unteren Rande der Zeichnung liegende) 7. Tergit ist sehr breit. Der Hinterrand des 6. Abdominalsegments (vordere Rand der Segmente) ist in der Mitte breit gerundet, an den Seiten leicht geschweift. Bei *S. melanopterus* (Mitte) sind die Segmente sehr gross, nur 1,4×

so breit wie hoch. Die Lappen des 7. Sternits sind fast dreieckig, etwa so hoch wie breit, ihr Hinterrand liegt etwa in der Mitte. Das 7. Tergit ist jedoch schmaler. Der Hinterrand des 6. Sternits ist in der Mitte spitzbogig, an den Seiten fast gerade. Bei *S. impressus* (unten) sind die Segmente am kleinsten, 1,6-1,8× so breit wie hoch. Die Lappen des 7. Sternits sind auffallend gross, hoher als breit, stark gerundet, ihr Hinterrand liegt weit hinter der Mitte. Das 7. Tergit ist sehr schmal. Der Hinterrand des 6. Sternits ist in der Mitte halbkreisfoermig und an den Seiten stark geschweift.

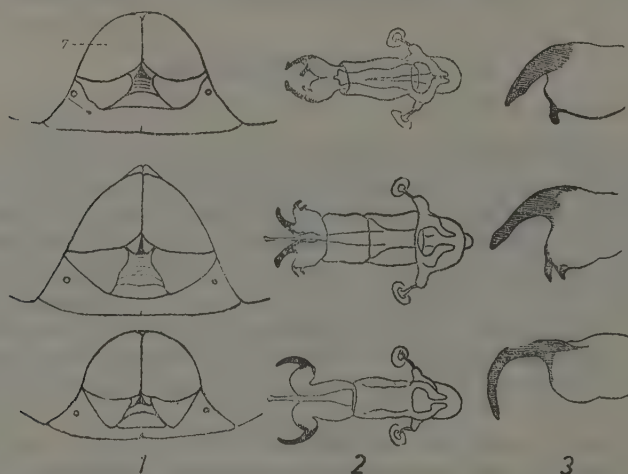


Fig. 1-3: Genitalien :

Obere Reihe = *S. dubius* Scop., mittlere Reihe = *S. melanopterus* H.S., untere Reihe = *S. impressus* Horv. — Fig. 1 = Genitalsegmente des ♀ von hinten (22,5×), Fig. 2 = Penis von oben, Vesika ausgestülpt (22,5×), Fig. 3 = Anhang der Vesika mit Chitinhaken (60×).

Beim ♂ ist die Trennung nur bei Zergliederung des Tieres moeglich. Die Betrachtung des Genitalsegments von aussen (Fig. 10+11) fuehrt zu keinen befriedigenden Ergebnissen. Es ist zwar bei *S. dubius* (oben) ebener als bei den beiden anderen Formen (Fig. 11) und bei *S. impressus* (unten) kuerzer und breiter als bei *S. dubius* und *melanopterus*; doch sind diese Unterschiede gering.

Aber bereits das herausgeloeste Segment zeigt deutliche Unterschiede, vor allem bei seitlicher Betrachtung (Fig. 7). Bei *S. dubius* (oben) ist seine Unterseite (in der Abb. rechts) gleichmaessig gerundet und auch vor der Spitze nicht eingebuchtet (Pfeil). Bei *S. melanopterus* (Mitte) dagegen ist die Unterseite vor der Spitze stark eingedrueckt, im uebrigen aber stark gewoelbt,

Bei *S. impressus* (unten) ist das Segment weit schmaler und ebener, der Eindruck der Unterseite vor der Spitze ist vorhanden, die Aussenseite im uebrigen aber weniger stark gewoelbt.

Bei Betrachtung des Segments von oben (Fig. 8) zeigen sich ebenfalls Unterschiede, Bei *S. dubius* (oben) fallen vor allem die fast spitzen Seitenecken und die in der Mitte kaum eingebuchteten Seiten auf. Bei *S. melanopterus* (Mitte) dagegen sind die Seitenecken etwas mehr gerundet und die Seiten in der Mitte stark eingebuchtet. Das Genitalsegment von *S. impressus* (unten) aehnelt in der Form mehr dem von *S. dubius*, es hat kaum eingebuchtete Seiten, aber die Seitenecken sind abgerundet und die Seiten divergieren nach hinten kaum.

Zergliedert man das Genitalsegment, so stoesst man im Bau des Penis (Fig. 2) auf ein vorzuegliches Trennungsmerkmal. Die Vesika traegt an der Spitze 2 Lappen, die mit Chitinhaken (Fig. 3) besetzt sind. Bei *S. impressus* (unten) ist jederseits nur 1 langer, gleichmaessig gekruemmter Haken vorhanden. *S. dubius* (oben) hat einen kurzen, weniger gekruemmten Haken, dessen Spitze oft haekelnadelartig ist, ausserdem aber sitzt auf der Innenseite des Lappens ein zweiter, kleinerer, stumpfer Chitinhaken. Bei *S. melanopterus* (Mitte) sind neben dem grossen noch 2 kleine Zaehne vorhanden, die ueberdies stets spitz sind, waehrend der grosse Haken schlanker und distal fast gerade ist. Diese Chitinhaken variieren nur wenig in ihrer Gestalt und Groesse und die hier angegebenen Merkmale liessen stets eine Trennung der 3 Formen zu.

Auch im Bau der Parameren (Fig. 4-6) zeigten sich Unterschiede. Bei *S. dubius* (oben) ist die Hypophysis kraeftig, stark gekruemmt, aufwaerts gerichtet und ueberragt den Paramerenkoerper weit nach oben. Der Paramerenkoerper ist kurz, distal stark verbreitert und abgerundet. Bei *S. melanopterus* (Mitte) ist der Griffel viel laenger und schlanker, die Hypophysis schlanker, distal weniger gekruemmt, stark zur Seite gerichtet und ueberragt den Paramerenkoerper kaum nach oben. Der Paramerenkoerper ist distal nur wenig verdickt, aber etwas spitzer. Bei *S. impressus* (unten) ist der Griffel kleiner, die Hypophysis fast gerade, noch schlanker, schraeg aufwaerts gerichtet und ueberragt den Paramerenkoerper deutlich. Der Paramerenkoerper ist distal verbreitert und hat eine deutliche Ecke. Auch diese Merkmale sind durchaus konstant, aber nicht immer leicht zu ermitteln, da es schwierig ist, mehrere Griffel in eine korrespondierende Lage zu bringen.

Es erwies sich als schwierig, andere sichere Merkmale zur Trennung der 3 Formen zu finden. Die Faerbung der Membran ist zwar ein recht gutes Merkmal, um *S. melanopterus* zu erkennen. Tiere mit schwarzbrauner Membran gehoeren, sofern sie aus Europa und dem Mittelmeergebiet stammen, immer zu dieser Form. Indessen sah ich von der Insel Zypern 10 ♂♂ und 10 ♀♀, die nach dem Bau der Genitalien einwandfrei zu *S. melanopterus* gehoeren, aber eine voellig helle Membran haben. Durch diese Tiere wird daher auch dies

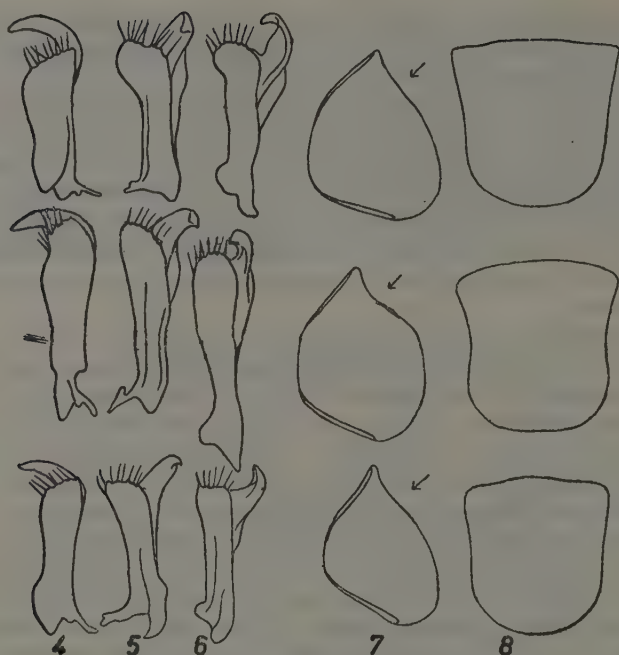


Fig. 4-8: Genitalien des Maennchens:

Oben = *S. dubius* Scop., Mitte = *S. melanopterus* H.S., unten = *S. impressus* Horv. — Fig. 4-6 = Parameren in verschiedenen Stellungen (60 \times), Fig. 7 = Genitalsegment seitlich (22,5 \times), Fig. 8 = dass. von oben (22,5 \times).

Merkmal entwertet. *S. dubius* und *S. impressus* haben immer eine helle Membran. Manche Autoren versuchen, die 3 Formen nach der Querfurche des Pronotums trennen. Aber auch dies Merkmal ist nicht zuverlaessig. Bei *S. melanopterus* ⁽¹⁾ ist die Querfurche stets schwach ausgepraegt und undeutlich. Bei *S. impressus* dagegen ist sie stets tief und sehr deutlich, seitlich endet sie in einer runden Grube. Bei *S. dubius* dagegen haben etwa 35% aller von mir untersuchten Tiere eine undeutliche Querfurche, bei etwa 28% war sie dagegen stark ausgepraegt und tief, waehrend der Rest Uebergangsformen zwischen beiden Extremen darstellte. So lassen sich durch dies Merkmal *S. melanopterus* und *S. impressus* gut trennen, aber gerade *S. dubius* ist nicht sicher zu erkennen.

Misst man die Groessenverhaeltnisse, so erkennt man, dass die durchschnittlichen Masse bei den 3 Formen deutliche Unterschiede zeigen. Indessen

(1) Indessen macht hier die var. *niger* Vid. eine Ausnahme.

variieren alle 3 Formen so stark, dass Ueberschneidungen eintreten und einzelne Stuecke sich nicht erkennen lassen. Andererseits aber zeigen die Unterschiede in den durchschnittlichen Massen deutlich, dass die 3 Formen auch hier von einander abweichen.

Der Scheitel ist bei *S. dubius* im Mittel $3,0\times$ so breit wie das Auge, es wurden jedoch Schwankungen zwischen $2,7\times$ und $3,3\times$ festgestellt. Bei *S. melanopterus* ist der Scheitel im Mittel $3,4\times$ so breit wie das Auge, die Extreme lagen bei $3,2$ und $3,55\times$. Bei *S. impressus* ist die Durchschnittszahl $3,4$, die Extreme liegen bei $3,0\times$ und $3,9\times$.

Ebenso verhalten sich die Laengen der Fuehlerglieder. Sie variieren derart stark, dass es unmoeglich war, sie fuer die Trennung der Formen zu verwenden. Die Fuehler sind zwar bei *S. impressus* im Mittel kuerzer und kraeftiger (Glieder 2-5 sind zusammen $0,42\times$ so lang wie der Koerper) und bei *S. melanopterus* auffallend lang und schlank (Glieder 2-5 zusammen im Mittel $0,49\times$ so lang wie der Koerper) waehrend bei *S. dubius* das Mittel zwischen diesen beiden assen liegt (Glieder 2-5 = $0,46\times$ so lang wie der Koerper), aber diese Unterschiede werden gleichfalls durch die grosse Variationsbreite voellig verwischt.

Auch die Laenge des Rostrums schwankt so stark, dass sie als Trennungsmerkmal nicht herangezogen werden kann.

Die matten Flaechen der Mittel- und Hinterbrust (Fig.9) dagegen zeigen deutliche Abweichungen. Die matte Flaechen der Hinterbrust hat ihre breiteste Stelle bei *S. dubius* (oben) mehr zu den Hueften hin, bei *S. melanopterus* (Mitte) liegt sie in der Mitte und bei *S. impressus* (unten) ist sie dem Aussenrande genaeht. Die matte Flaechen der Mittelbrust ist bei *S. melanopterus* sehr schmal, ihr Vorderrand stumpfwinklig, bei *S. impressus* (unten) dagegen viel breiter und ihr Vorderrand in einem fast spitzen Winkel ausgezogen. *S. dubius* (oben) nimmt eine Zwischenstellung zwischen beiden Arten ein. Die lappenartige Flaechen, auf der die Ablaufrinne der Stinkdruesen liegt, ist bei *S. dubius* fast dreieckig, aussen fast spitz und reicht weit nach aussen. Bei *S. melanopterus* ist sie fast parallelseitig und aussen breit gerundet. Bei *S. impressus* ist sie leicht gekruemmt, fast oval und aussen spitz gerundet.

Ein geringer Unterschied zeigte sich auch in der Form des Kopfes. Die Raender desselben sind bei allen Arten stark aufgebogen, so dass der Kopf vor den Augen schuesselfoermig ist. Bei *S. impressus* ist die Stirn in dieser Schuessel zwischen den unteren Augenecken gewoelbt, bei beiden anderen Arten voellig eben.

Die von Stichel (Ill. Best.-Tabellen d. deutsch. Wanz., pag. 10) angegebenen Unterschiede wurden durch meine Untersuchungen nicht bestaetigt.

Wir muessen also feststellen, dass hier 3 Formen vorliegen, die sich zwar durch den Bau der Genitalien gut trennen lassen, deren uebrige Unterschiede

aber stark in einander uebergehen. Es erhebt sich unnn die Frage, wie diese 3 Formen zu bewerten sind. Auf keinen Fall kann es sich hier um Varietaeten handeln, wie viele Autoren annehmen. Dagegen sprechen die doch vorhandenen Unterschiede und vor allem der Bau oder Genitalien. Es koennten aber 3 Rassen eines Rassenkreises sein; denn die 3 Formen sind auch geogra-

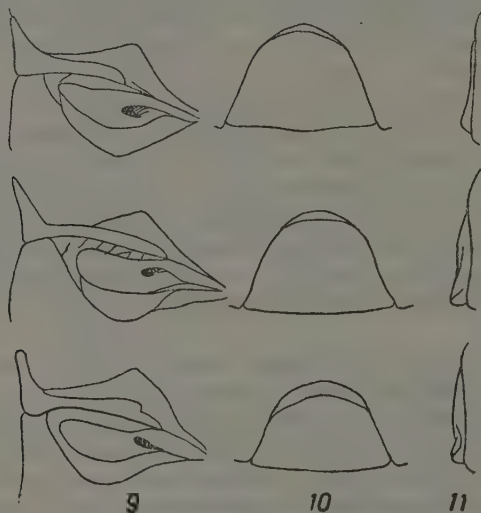


Fig. 9-11: Bruststücke und Genitalsegment des ♂ (22,5×) :

Oben = *S. dubius* Scop., Mitte = *S. melanopterus* H.S., unten = *S. impressus* Horv. — Fig. 9 = Matte Flaechen der Mittel- und Hinterbrust, Fig. 10 = Genitalsegment von hinten, Fig. 11 = dass. seitlich.

phisch und oekologisch getrennt. Fuer diese Annahme wuerde sehr viel sprechen, vor allem auch die geringen Unterschiede in den aeusseren Merkmalen. Andererseits bleibt als 3. die Moeglichkeit, alle Formen als Arten aufzufassen, wie es neuerdings Priesner und Alfieri (*Bull. Soc. Fouad I Entom.*, XXXVII, 1953: 9) tun. Um diese Frage zu entscheiden, wurden noch einmal die Verbreitungsgebiete und die Lebensweise eingehend untersucht. Dabei zeigten sich wiederum sehr deutliche Unterschiede. *S. impressus* ist eine ausgesprochen alpine Form und kommt nur in Hoehen von 1800-2500 m. vor. Mir lagen Stuecke vor aus der Schweiz (Davoser Tal, Val Zavretta), Tirol (Stilfser Joch), Kaernten (Heiligenblut), Deutschland (Oberstdorf), Italien (Trentino), Albanien (Korab, Gjalica Ljums) und Serbien (Shar Dag, Ljuboten). Alle diese Fundorte liegen in Hoehen von etwa 2000 m. oder ihre Umgebung steigt bis zu solchen Hoehen, in vielen

Faellen liegen auch klare Hoehenangaben vor. Auch Horvath meldet seine Art nur aus Kaernten und Kroatien. Die Angabe, dass sie auch in der Ebene vorkomme, duerfte auf Verwechslung mit *S. dubius* geruhen. Als Wirtspflanze wurde nur *Thesium alpinum* angegeben. *S. melanopterus* ist mediterran. Ich sah Tiere aus Spanien, Suedfrankreich, Italien, Sizilien, Oesterreich (nordwaerts bis Bisamberg), Dalmatien, Jugoslawien, Albanien, Griechenland, Kreta, Tuerkei, Syrien, Palaestina, Persien, Suedrussland, Armenien, Zypern, Aegypten, Tripolis, Tunis, Algier, Marokko und von den Kanarischen Inseln. Horvath meldet sie aus Ungarn. Sie bewohnt also das ganze Mittelmeergebiet und in Frankreich und Oesterreich + Ungarn) zeigt sich ein Uebergreifen nach Mitteleuropa. Als Wirtspflanze wurde *Osgris alba* gemeldet. *S. dubius* bewohnt Mitteleuropa (Deutschland nordwaerts bis zum Rhein- und Maingebiet, Oesterreich (in den Alpen an vielen Orten in geringerer Hoehe), Schweiz (ebenso), Frankreich (suedwaerts bis in die Pyrenaeen), Italien (nur im Norden, suedwaerts bis zum Garda-See), kommt aber ausserdem auf der Balkanhalbinsel in Dalmatien, Montenegro und Albanien (Suedwaerts bis Pashtrik) und in Suedrussland (bis zum Kaukasus) vor. Die Art wurde at *Thesium pratense* Ehrh., *Th. linophyllum* L. und *Th. bavarum* Schrk. gefunden.

Es zeigen sich also an vielen Orten Ueberschneidungen der Verbreitungsgebiete. So kommen *S. dubius* und *S. melanopterus* nebeneinander vor in Suedfrankreich, Norditalien (Garda-See, Triest), Dalmatien, Albanien und Suedrussland. *S. impressus* und *S. dubius* leben nebeneinander im ganzen Alpengebiet und in Albanien. In Albanien und Norditalien (Trentino) konnten sogar alle 3 Formen festgestellt werden, ebenso im westlichen Alpengebiet. Diesen Funden wurde besondere Aufmerksamkeit gewidmet, aber es zeigte sich, dass die 3 Formen sich auch dort gut trennen liessen. Es konnten auch keine Uebergangsformen festgestellt werden, selbst dort, wo Tiere vom gleichen Fundort vorlagen. Diese Tatsache beweist, dass es sich hier um Arten handelt.

Um diese Feststellung zu ueber rufen, wurde auch der nahestehende *S. niveimarginatus* Scott in die Betrachtung einbezogen. Die Untersuchung ergab, dass die Genitalien bei dieser Art (Fig. 13-21) keineswegs staerker abweichen als bei unseren 3 Formen. Die Genitalsegmente des ♀ (Fig. 12) haben Aehnlichkeit mit denen von *S. impressus*, sind jedoch schmaeler und hoeher. Das Genitalsegment des ♂ (Fig. 13, 14, 15) erinnert an *S. dubius*, weicht aber dadurch ab, dass es in der Mitte ploetzlidh verjuengt ist. Auch die Parameren (Fig. 17, 18, 19) aehneln durchaus denen der 3 Formen, weichen aber von ihnen dadurch ab, dass der Paramerenkoerper stark nach oben vorspringt. Im Bau der Vesikalanhaengep asst die Art gleichfalls gut in unsere Gruppe. Sie tragen einen sehr langen, schlanken groesseren Haken und daneben einen kleinen Zahn. Das erinnert an *S. dubius*, weicht aber doch

deutlich ab. Die matten Flaechen der Bruststuecke (Fig. 16) haben etwa die Form wie bei *S. melanopterus*, doch ist die zungenfoermige Flaechе, auf der die Ablaufrinne der Stinkdruesen liegt, sehr klein und schmal. Der Scheitel ist im Mittel beim ♂ $3,3\times$, beim ♀ $3,6\times$ so breit wie das Auge, das 2.-5. Fuehlerglied sind zusammen im Mittel $0,40\times$ so lang wie der Koerper. Die Querfurche des Pronotum ist aehnlich wie bei *S. impressus* gebaut, laeuft aber an den Seiten flach aus. Auch sonst zeigt die Art gegen unsere 3 Formen

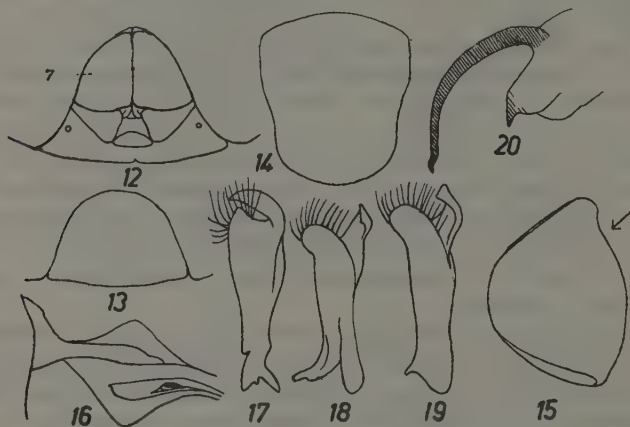


Fig. 12 = Genitaliaen von *S. melanopterus contrarius* nov. subsp.: Oben=Vesikal-anhang, Mitte und unten Parameren ($60\times$)

Fig. 13-20: *S. niveimarginatus* Scott :

Fig. 12 = Genitalsegmente des ♀ von hinten ($22,5\times$), Fig. 13 = Genitalsegment des ♂ von hinten ($22,5\times$), Fig. 14 = dass. von oben, Fig. 15 = dass. von der Seite, Fig. 16 = Matte Flaechen der Mittel- und Hinterbrust ($22,5\times$), Fig. 17-19 = Parameren des ♂ in verschiedenen Stellungen ($60\times$), Fig. 20 = Anhang der Vesika des ♂ ($60\times$).

keine groesseren Abweichungen als sie diese unter sich zeigen. Auch diese Feststellungen beweisen, dass es sich hier um Arten handelt. Da sich ueberdies auf der Insel Zypern eine abweichende Form findet, die nur als Rasse von *S. melanopterus* gedeutet werden kann, bleibt keine andere Moeglichkeit, als die 3 Formen als Arten aufzufassen.

Leider konnte die von Vidal 1949 (*Mem. Soc. Sciences Nat. Maroc*, XLVIII : 42/43) beschriebene var. *nigra* nicht untersucht werden. Fuer sie gibt Vidal den gleichen Bau des Pronotum an, wie ihn *S. impressus* Horv. zeigt. Da die Tiere im Atlasgebirge (Marokko) in Hoechen zwischen 2500 und 2800 m. gefunden wurden, liegt die Vermutung nahe, dass es sich um eine Rasse von *S. melanopterus* handelt, die ein Gegenstueck zu der auf Zypern lebenden Rasse bilden wuerde. Mir lag ausserdem 1 ♂ aus Tripolis (Bir el

Gnem, V. 38, G a l v a g n i leg.) aus der Sammlung T a m a n i n i vor, auf das die V i d a l s che Beschreibung gut passt mit Ausnahme der Faerbung. Das Tier hat eine blauglaenzende Oberseite; doch messe ich diesem Merkmal keine Bedeutung zu. Die Untersuchung seiner Genitalien ergab (Fig. 24-26), dass sie zwar von denen von *S. melanopterus* ein wenig abweichen, aber das Tier doch ohne Zweifel zu *S. melanopterus* gehoert. Die Parameren (Fig. 25+26) stimmen sogar recht gut mit dieser Art ueberein. Die Anhaenge der Vesika tragen wie bei *S. melanopterus* einen grossen und 2 kleine Haken

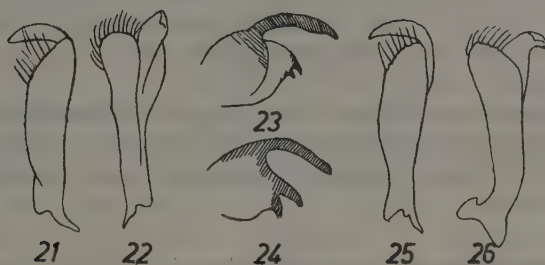


Fig. 21-26: Rassen von *S. melanopterus* H.S.:

Fig. 21-23 = *S. melanopterus contrarius* nov. subspec., Fig. 24-26 = *S. melanopterus* H.S. von B i r e l G n e m (*niger* Vid. ?), Fig. 21, 22, 25+26 = Parameren des ♂ in verschiedenen Stellungen (60×), Fig. 23+24 = Anhang der Vesika des ♂ (60×).

(Fig. 24). Letztere sind jedoch kraeftiger entwickelt und stumpf. In der Form der matten Flaechen der Bruststuecke und der Form des Genitalsegments stimmt das Tier gut mit *S. melanopterus* ueberein, ebenso im Bau der Fuehler und des Kopfes. Der Scheitel ist $3,1 \times$ so breit wie das Auge. Das Pronotum hat eine kraeftige Querfurche, deren Raender jedoch abgeschraegt sind und die in der Mitte durch einen undeutlichen Laengskiel unterbrochen ist. Im uebrigen stimmt es mit *S. melanopterus* ueberein. Ich stelle es daher zu der var. *nigra* Vid. dieser Art, die jedoch vermutlich als Rasse betrachtet werden muss.

***Sehirus melanopterus contrarius* nov. subspec.**

Beschreibung: Von auffaellend kleiner, aber schlanker Gestalt, das ♂ 5,0-6,1 mm, das ♀ 6,2-6,7 mm lang und beide etwa $2 \times$ so lang wie an den Schultern breit. Blaeuilich-violett, glaenzend. Fuehler verhaeltnismaessig schlank, aber kurz; Glied 2-5 zusammen $0,44-0,46 \times$ so lang wie der Koerper. Scheitel verhaeltnismaessig breit, beim ♂ $3,3-3,5 \times$, beim ♀ $3,6-4,0 \times$ so breit wie das verhaeltnismaessig kleine Auge. Pronotum mit flacher, kaum merklicher Querfurche. Membran bei allen Tieren hell, weisslich. Genitalien aehnlich der Nominatrasse. Genitalgriffel des ♂ (Fig. 21+22) etwas kleiner, Paramerenkoerper distal mehr abgerundet, Hypophysis kleiner und schlanker.

Der grosse Haken am Vesikalanhang des Penis ist schlanker und spitzer (Fig. 23).

Die Tiere machen durch ihre kleine, schlanke Gestalt und ihre weissliche Membran einen derart abweichenden Eindruck, dass ich sie als besondere Rasse betrachte. Vermutlich sind die unter dem Namen *dubius* von der Insel Zypern gemeldeten Tiere alle diese Rasse.

Ich untersuchte 10♂♂ und 10♀♀ von der Insel Zypern: Ayos Hilarion 7.6.39, 5♂♂, 1♀; Troodos-Geb., Platania 18.-23.6.39, 2♂♂, 1♀, Mesopotamos 21.4.39, 1♂, Prodhomos 19.6.39, 1♀, Troodos 14.-22.4.39, 2♂♂, 2♀♀; Aya Napa 10.7.39, 1♀; Trikomo 10.6.39, 1♀; Larnaka 25.6.-1.7.39, 1♀ (saemtlich H. Lindberg leg.); Troodos Gebirge (Coll. Werner), 1♀, und Episkopi 1♀ (Mavromustakis leg.), 1♀.

Holotypus und Paratypoiden in der Sammlung H. Lindberg, Helsingfors, Allotypoid und Paratypoiden in meiner Sammlung, Paratypoid auch in der Sammlung des Naturhistorischen Museums in Wien.

Bestimmungstabelle der Arten der *Sehirus dubius*-Gruppe

- 1 (2) Aussenrand von Pronotum, Corium und Abdomen von gleicher Farbe wie die Oberseite.....1. ***S. coeruleus* Reut.**
- 2 (1) Aussenrand von Pronotum, Corium und Abdomen groesstenteils schmal gelbweiss.
- 3 (4) Aussenrand des Abdomen in ganzer Laenge schmal gelbweiss.....2. ***S. niveimarginatus* Scott**
- 4 (3) Aussenrand des Abdomen abwechselnd gelbweiss und schwarz.
- 5 (8) Membran schwarzbraun.
- 6 (7) Querfuerche des Pronotum flach, undeutlich. Grundfarbe blau oder violett, selten schwarz. Genitalsegmente des ♀ spitzbogig (Fig. 1, Mitte). Vesikalanhang des ♂ mit 1 grossen und 2 kleinen Zaehnen 3. ***S. melanopterus* H.S.**
- 7 (6) Querfuerche des Pronotum tief und deutlich. Grundfarbe schwarz ⁽²⁾, seltener blau**var. *nigra* Vid.**
- 8 (5) Membran weisslich.
- 9 (10) Stirnmitte vor den Augen gewoelbt. Vesikalanhaenge des ♂ nur mit 1 grossen Haken, ohne kleine Zaehne. Querfuerche des Pronotum tief und deutlich. Genitalsegmente des ♀ klein, mit stark geschweiften Seiten (Fig. 1, unten)4. ***S. impressus* Horv.**

(²) Tiere mit rein schwarzer Oberseite habe ich bisher nur wenige gesehen, obgleich ich mehr als 1000 Exemplare untersuchte. Dagegen fand ich mehrfach als *S. melanopterus* H.S. bestimmte Tiere, die sich aber bei naeherer Betrachtung als *S. biguttatus* var. *concolor* Nick. erwiesen.

- 10 (9) Stirnmitte vor den Augen eben. Vesikalanhang des ♂ mit einem grossen Haken und 1 oder 2 kleinen Zaehnen. Querfurche des Pro-notum oft flach, aber bisweilen auch tief. Seiten der Genitalsegmente des ♀ nicht stark geschweift.
- 11 (12) Genitalsegmente des ♀ 1,6-1,7 × so breit wie hoch, gerundet (Fig. 1, oben). Vesikalanhang des ♂ neben dem grossen Haken mit 1 stumpfen Zahn5. **S. dubius Scop.**
- 12 (11) Genitalsegmente des ♀ 1,4 × so breit wie hoch, spitzbogig (Fig. 1, Mitte). Vesikalanhang des ♂ neben dem grossen Haken mit 2 kleinen, spitzen Zaehnen (Fig. 12).....**S. melanopterus contrarius nov. subspec.**

Ich moechte nicht versaeumen, den Herren zu danken, die mir bei den Untersuchungen zu dieser Arbeit durch Ausleihen von Material und Auskuenfte behilfflich waren. Es sind dies Herr Prof. H. Lindberg, Helsingfors, Herr Prof. H. Priesner, Kairo, Herr Dr. M. Beier, Wien, Herr Dr. L. Tamanini, Rovereto, Herr Dr. H. Eckerlein, Coburg, Herr G. Seidenstuecker, Gunzenhausen und Herr H. Weber, Nortorf.

SCHRIFTEN-NACHWEIS

- Herrich-Schaeffer (1835) : Nomencl. Ent., p. 55.
 Horvath, G. (1880) : Termeszetr. Fuezet., IV, p. 184.
 Scopoli, E. C. (1763) : Ent. Carniol., p. 122.
 Vidal, H. (1949) : *Mém. Soc. Sc. Nat. Maroc*, XLVIII, p. 43.

Biological studies on the Egyptian honeybee, *Apis mellifera fasciata* Latr.

[Hymenoptera : Apoidea-Apidae]

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INTRODUCTION

The present investigations were carried out to study the biology of the three castes of the Egyptian honeybee, as regards the duration of each developmental stage and the variations occurring into the external features of the brood.

The experiments were carried out, in movable-frame Langstroth hives, to give the colonies the chance for free extension. Although each colony had ample space for multiplication, yet it rarely increased sufficiently enough to cover seven combs during the honeyflow, producing little amounts of honey stores.

Bertholf (1925) observed by sufficient magnification, that the egg of the bee, when prepared for hatching, had the appearance of a larva, according to the transparency of the chorion, but he found that the larva was covered by the chorion until a drop of water or larval food was added. He showed that four moults occurred in the larval stage of the three castes of honeybee, during the unsealed period, and the fifth (which is the last larval moult) taking place when changing from pre-pupa to pupa, in the cocoon. He mentioned that the sixth or final moult occurred at the end of the pupal stage just before emerging. He stated that the incubation of the egg stage of each caste was completed in three days, and queen larva was sealed over on the eighth day, and the drone larva was sealed on the tenth day. The pre-pupal stage was less than one day in the cases of a queen, but lasted two days in the case of a worker, and four days in the case of a drone. The pupa stage lasted five days in the queen as against nine in the worker, and eight

to nine days in the drone. Thus, the queen emerged on the sixteenth day, the worker on the twentieth or twenty-first day, and the drone emerged on the twenty-fourth day. He observed also the colouration of the worker pupae until maturing beginning in the eyes, then joints of the legs, gradually spreading over the whole body.

Milum (1930) showed that temperature had great influence upon the developmental periods of eggs, larvae and pupae of the three castes. In any colony the shortest periods of development were those of the brood in the centre of the combs, in the center of the brood nest, the length of time increasing for the brood towards the periphery of the brood nest or that brood on the lower edges of the frames and in the outside frames. The amount of feeding by the nurse bees might influence the developmental period, depending upon the strength of the colony and the relative amount of nurse bees and brood. He found also that the majority of worker brood were capped during the ninth day after the laying of the eggs, some brood might be capped before the eighth day, and some required as much as eleven days before being capped. Some cells were capped several hours before others in the immediate vicinity, probably due to differences in the rate and amount of feeding by the nurse bees. The complete developmental period for worker bees varied from less than nineteen days to more than twenty four-days according to the temperature.

METHOD

It was necessary for the investigations of the developmental periods of each stage of the three castes of the Egyptian honeybee, to begin with eggs newly laid. An empty comb, having a mark on the frame, was inserted in the middle of the experimental hive, and was examined daily for eggs. The cells of this comb were of the worker size when studying the biology of workers or queens, but combs of drone cells were used when studying the biology of drones.

When eggs were found to be laid in the cells, a relatively considerable area full of eggs of the same age were bordered by slices of wood, and the date of egg-laying was written on a sheet of paper (or map) having hexagonal drawings of the same area of cells used. An equal number of cell-shapes on the map, were surrounded by lines, forming the same shape of the experimental area of eggs. Thin slices of wood were prepared to facilitate the examinations, of 2, 3, or 4 inches in length. Results were recorded on the map as quickly as possible, to avoid any damage of brood which might be caused by the effect of cold weather or the direct sun rays.

Cells containing larvae, hatching on the same day, were distinguished by drawing horizontal lines on the hexagons that represent them on the

map, using different colours for successive days.

The capped cells were marked on the maps by vertical lines, using different colours for different dates. In the same way, the dates of emerging were recorded on the maps, using oblique lines.

From the above described maps, the duration of each developmental stage could be estimated.

It was necessary for studying the developmental periods of the queens, to remove the original queen, to observe the building of queen cells, and recording the observations on the maps. Artificial ways of queen rearing were sometimes used by transferring larvae of known ages, to artificial cell cups.

Caging queen cells was necessary after five days of sealing, to avoid their destruction on the emergence of the first queen. If it was impossible to cage the queen cells, for their density, the whole comb was transferred to an incubator on 33°C., provided with suitable humidity.

A. THE BIOLOGY OF THE WORKERS

1. Duration of the incubation period

The results on the period after which the worker eggs hatch in the Egyptian colony of honeybees show that it varies from 2 to 5 days. These variations do not show any direct correlation with the seasons, because the temperature is not the sole factor influencing the incubation period. Larval food (Royal jelly) should be provided to allow the larva to escape from the egg shell. It was also observed that the incubation period varies in the cells of the same area for several hours or even for more than a day, especially in weak colonies. Few eggs were seen hatching before the end of the third day of egg-laying. Hatching frequently happens after three days, specially during the honeyflow. The mean length of the incubation period of Egyptian worker honeybees was 3.12 ± 0.016 days.

2. Duration of the larval period

The results show that the larval period of the workers varies from 3 to 7 days. This period is lengthened obviously by less feeding or less temperature, or by the two factors. The frequent duration of the larval period varies between 4 and 5 days, specially during the honeyflow, when food is available for nurse bees, and the temperature is suitable for brood rearing. During the dearth, the period is frequently ranging between 5 and 6 days. The position of the comb within the hive has also some effect on the larval period. It was found also that the larvae of the same age and which hatched from the same batch of eggs, were sealed over after a period that varied from

each other by same hours, and sometimes by more than a day. Few larvae were found to be sealed before the beginning of the fourth day after hatching, these individuals were probably fed for a period less than 4 days by few hours. The absolute mean duration on the larval period of the Egyptian workers was 4.72 ± 0.01 days.

3. Duration of the sealed period

The observations show that the sealed period varies from 9 to 14 days. Individuals emerging before the tenth day or after the thirteenth day of sealing, were very few. The Egyptian worker bees usually emerge after 11-12 days from sealing. This period obviously depends upon the temperature of the brood nest. The absolute mean of duration of the sealed period was 11.64 ± 0.01 days.

4. Duration of the total developmental stages

The duration from the egg to adult development occurs in 17-22 days. It is shorter during the honeyflow than during dearth. Eggs laid on the same day, and which are incubated under the same conditions, produce adult workers after periods varying from each by several hours and sometimes by three days. The average of the period spent in the cell, since egg-laying till the emergence of the adult Egyptian workers honeybee, is 19.43 ± 0.03 days.

5. Further studies on the development of the larval and pupal stages

After sealing over the larval stage, the cocoon is spun during a day, then the larva passes gradually and without moulting into the pre-pupal stage. After a period ranging between 3 and 4 days of sealing over the larva, it moults its larval skin, and there emerges the young pupa, motionless, uniformly white in colour and lying on its back. A number of sealed worker cells were observed in the incubator under 33°C . and suitable humidity, after cutting off their cappings, to study the external changes occurring upon their larvae: 153 larvae were found to change to pupae after 3 days of sealing over, and 223 were found to pupate after 4 days. The mean length of this pre-pupal stage was 3.59 ± 0.027 days. On the fifth or the sixth day after being sealed or after about two days of pupation, colour begins to appear in the eyes, light pink at first, then gradually darkening, until after another three days it is decidedly purple, showing a somewhat blue colour darkening gradually and more distinguished on the following days, but when the adult emerges it changes to brown. A pale yellow colour spreading over the

body and the legs, accompanies the appearance of the purple colour in the eyes. On the last day before emerging, the antennae and the mouth-parts become dark brown, while the thorax obtains a hairless grey colour, and the legs light brown. Then light grey colours appear on the posterior margins of the abdominal tergites. By the moulting of the pupal skin, there appears the adult worker honeybee with her yellow colours on the first three abdominal tergites, and her white hairs spreading over all the body.

B. THE BIOLOGY OF THE DRONES

1. Duration of the incubation period

The male eggs hatched after a period of incubation varying from 3 to 6 days, although they were all laid in the course of 3 days, in May 1953, during the main period of honeyflow. This period depends, as it is known, on the presence of royal jelly. Eggs laid on the same day might hatch after different periods. The general means of this period was 4.66 ± 0.08 days.

2. Duration of the larval period

The drone larva is sealed over after a feeding period which varies from 4 to 7 days. Under the same conditions, there may be some variations which sometimes reach a period of two days. These larvae, which sealed after a period less than 5 days, were few. The general mean of this period was 5.68 ± 0.03 days.

3. Duration of the sealed period

The adult drones emerged after being sealed over by a period ranging between 10 and 15 days. Under the same conditions, there might be variations reaching 5 days. The general mean of the time spent by drones under the wax cappings was 13.76 ± 0.04 days.

4. Duration of the total developmental stages

Observations show that the male egg took a period of the time varying from 21 to 27 days, before producing an adult drone. In general, the delay in the hatching of the eggs, postponed the emerging of the adult. There were also some variations occurring between drones reared under the same conditions. The general mean of the period spent in the cell from egg-laying until the emergence of the adult drone, was 24.49 ± 0.10 days.

5. Further studies on the development of the larval and pupal stages

The drone larva when sealed over spins its cocoon during 2 days, then

stretches out on its back and resting inside the cocoon for about 3 days, after which it moults changing to a white and motionless pupa. A comb containing 64 sealed drone cells was observed in an incubator after cutting off their cappings, 20 of them pupated after 4 days, and 44 pupated after 5 days of sealings. The mean duration of this pre-pupal stage was 4.69 ± 0.058 days. After about 2 days of pupation a light purple colour appeared in the large eyes, getting gradually darker and darker on the following days. In two days, the colour of the eyes was transformed to light violet. The blue colour accumulated and increased gradually on the following days, until on the twelfth day after sealing, the eyes of the drone pupa were decidedly blue. Then the adult drones emerged on the fourteenth day after shedding off the pupal skin and gaining the natural colours on all the body.

C. BIOLOGY OF THE QUEENS

1. Duration of the incubation period

Since fertilized eggs may become either queens or workers, the egg stage of both castes is of course identical, thus the egg period of workers or queens is the same if reared under the same conditions. If the original queen of a colony is raised leaving some fertilized eggs, these eggs usually hatch after 3 days which is the shortest period of this stage. The mean duration of this period in the investigations was 3.01 ± 0.01 days. This happened obviously under the impulse of needing a queen duration the shortest time, to replace the lost one.

2. Duration of the larval period

The queen larva was fed for a period varying from 3 to 6 days. The queen cells were usually sealed after 4 or 5 days from hatching, while the periods lasting 3 and 6 days were very rare that the first was thought to be less than 4 days by few hours and the latter more than 5 days by few hours also. The general mean of the feeding period was 4.34 ± 0.04 days.

3. Duration of the sealed period

Experiments on the sealed period of the Egyptian queen bees show that they spent 6 to 9 days under the wax cappings, before emerging. Although the queen cells reared on a certain day, were reserved under the same conditions, there were found some variations of several hours and sometimes of about 3 days, between the emergence of the first queen and the last one. The average period was ranging from 7 to 9 days, and the general mean was 7.81 ± 0.01 days.

4. Duration of the total developmental period

Queens could be reared from the eggs or the young larvae which might produce workers, so the egg period of queens was not always recorded. The period after hatching until the emergence of the queen was found to vary from 11 to 14 days, and rarely to 16 days. The mean of this period was 12.4 ± 0.08 days. The total duration of the developmental stages within the queen cell, since egg-laying till the emergence of the adult queen was averaging 15.41 days, by adding 3.01 days which was the average duration of the incubation period.

5. Further studies on the development of the larval and pupal stages

The queen larva was found to pupate after 2 days and sometimes after 3 days of sealing. The white eyes of the pupa were transformed to light pink after one day, then darkening on the second day. On the third day after pupation, the colour was changed to light purple being more dark on the fourth day. The frons, the antennae and the abdomen were coloured during the last day before emerging. The adult queen usually emerged on the seventh or the eighth day after sealing and after shedding of the pupal skin.

SUMMARY

The worker caste spends 19.43 ± 0.03 days in the cell since egg-laying till the emergence of the adult as follows : 3.12 ± 0.02 days in the egg stage, 4.72 ± 0.01 days in the larval stage, and is sealed over for 11.64 ± 0.01 days. The larval pupates after 3.59 ± 0.03 days from sealing, and after about two days of pupation, colour begins to appear in the eyes; pink at first then purple after another three days. The eyes' colour darkens gradually afterwards with the appearance of colour on the other body parts.

The drone takes 24.49 ± 0.10 days from egg-lying till the emergence of the adult as follows : 4.66 ± 0.08 days are spent in the egg stage, 5.68 ± 0.03 days in the larval stage, and 13.76 ± 0.04 days in the pre-pupal and pupal stages. The pre-pupal stage after which the drone larva pupates, is 4.69 ± 0.06 days after sealing. The colour of the eyes appears after 2 days of pupation, purple at first and violet after another 2 days. It darkens gradually until it gives blue colour. The body's colours appear gradually until the emergence of the adult.

The queen-bee takes 3.01 ± 0.01 days in the incubation period of the egg stage, and spends another 12.4 ± 0.08 days until emerging. The duration of the larval period is 4.34 ± 0.04 days, and the sealed period lasts for 7.81 ± 0.01 days. The larva pupates after 2-3 days of the sealing over, and pupa shows a light pink colour in the eyes after one day, then reddish purple on the

fourth day. The colours of the body appear gradually on the following days, until shedding off the pupal skin.

REFERENCES

- Bertholf, L.M. (1925) : The moults of the honeybee (*Jour. Econ. Entom.*, XVIII, pp. 380-384).
- Milum, V.G. (1930) : Brood rearing temperature and variations in the developmental periods of the honeybee (*Ann. Report Illinois Beekeepers Assoc.*, 72-95).
- Ruttner, F., and Mackensen, Q. (1952) : The genetics of the honeybee (*Bee World*, XXXIII, pp. 53-62).
- Snodgrass, R.E. (1925) : Anatomy and physiology of the honeybee (McGraw-Hill, New-York).
- Woodrow, A.W. (1935) : Some effect of relative humidity on the length of life and food consumption of the honeybee (*Jour. Econ. Entom.*, XXVIII, pp. 186-187).
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On the control of the Olive-tree scale,
Leucaspis riccae Targ.,
at Burg El-Arab, Egypt

[Hemiptera: Coccoidea]

(with 1 Text - Figure and 6 Tables)

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C O N T E N T S

Introduction. — Literature review. — Materials and methods — Experimental results. — Discussion and conclusions. — Summary. — Acknowledgments. — Literature cited.

INTRODUCTION

Cultivation of Egyptian deserts is one of the main constructive projects recently started in Egypt. One of the desert areas chosen for this purpose is that of Burg El-Arab, about 30 miles west of Alexandria and about 2 miles from the Mediterranean beach. In this region, different types of plants including almonds, figs, apples, pears, peaches, and olives, have been introduced. Of these types, olive trees proved to grow most successfully, as they require the least amount of water. The meteorological conditions and particularly the amount of rain fall at this region (Table I) seem to be more favorable for olives than to other trees. This fact encouraged planting of olives at this area, where artificially obtained water is very costly to get.

Although olive trees flourished best in this district, yet they suffer from certain insect pests, among which is the Olive-tree scale, *Leucaspis riccae* Targ. (Fig. 1). The seriousness of this infestation called for the chemical control programme applied by the Ministry of Agriculture, consisting in the use of petroleum oil sprays (volk and albolium at concentrations of about 1.75%).

TABLE I

Meteorological readings for the year 1952 at the Alexandria air-port station (according to specialists, conditions are similar to those at Burg El-Arab). — Data after Ministry of War and Marine records.

MONTH	MEAN TEMPERATURE	MEAN HUMIDITY	RAIN FALL IN MILLIMETRES
January	13.4	75	34.8
February	14.2	71	31.3
March	15.8	64	10.2
April	18.5	64	—
May	21.0	70	1.6
June	23.4	73	trace
July	25.4	75	—
August	26.5	75	—
September	26.4	73	—
October	23.2	69	17.4
November	19.2	69	18.1
December	16.4	72	17.1

In spite of carrying regularly for quite a number of years, the infestation remained rather severe. This is attributed to various reasons of significance among which, from the author's point of view, are the following :

(1) Scale insects are the most difficult pests to control, because they pass most of their life covered underneath scales of their own secretion.

(2) The insecticides are not applied at a high enough concentration.

(3) The non-efficiency of the insecticides in general, in controlling these insects under conditions prevailing in the mentioned area.

(4) The possibility of not hitting certain infested parts by the insecticide spray and thus the insects thereupon escape the effect of the treatment. This occurs more likely in cases of dense foliage or where the spray is not applied carefully at a high pressure.

(5) Difficulties preventing the application of the insecticide at the right time, on appearance of crawlers. Responsible for such limitations are many factors, most particularly the great extension and discontinuity of the crawlers emergence period due to the suitable weather conditions that usually prevail almost all the year round in Egypt, as well as the interference of the blossoming season.

This situation enthused the author to think of using a better control means where these difficulties are overcome. Materials tried in other countries proved in many occasions to be effective for the control of insects similar to that encountered at present. As can be grasped from recent literature, Parathion and similar other phosphorous insecticides have been commonly applied elsewhere in leading countries for combating many scale insects.

However, such chemicals should be used with great precautions. They have to be applied only by highly trained labourers and in the presence of responsible experts.

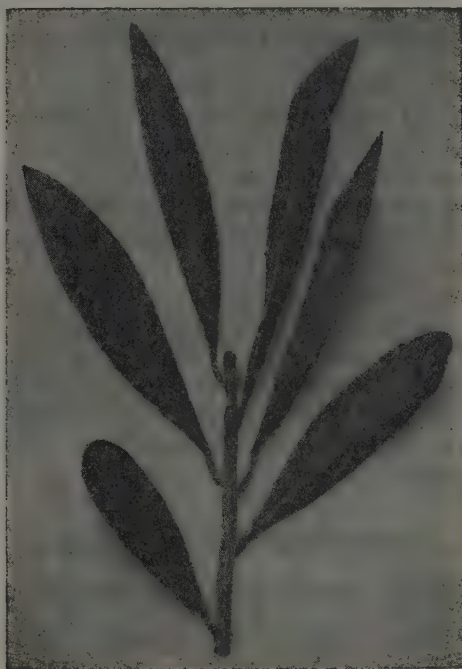


Fig. 1 : Olive tree leaves infested with the olive tree scale insect, *Leucaspis riccae* Targ.

In the present study two phosphorous insecticides, Parathion and Tetrax, were compared with a petroleum oil (Volk) for the control of the Olive-tree scale, *Leucaspis riccae* Targ. (In a previous preliminary experiment, these chemicals were applied for control of other scale insects, *Chrysomphalus ficus* (Riley) on Ficus trees, *Parlatoria oleae* Colvée on Olive trees, and *Asterolecanium sambuci* Ckll. on Eucalyptus trees, with encouraging results in each case).

LITERATURE REVIEW

Several authors studied the effect of Parathion in comparison to other materials for the control of various scale insects. The most recent investiga-

tions of this nature are these made by Stafford (1949), Bottger et al (1949), Spencer et al (1952 and 1953), Turnipseed et al (1953), and others. Results in each case indicate the efficiency of Parathion and its superiority to many other materials for this purpose.

MATERIALS AND METHODS

One of the heavily infested Olive-tree plots was chosen for this experiment. Parathion, Tetrax and a petroleum oil emulsion (Volk) were applied as sprays in this study. Each insecticide formulation was applied on one tree section of two rows, with ten plants in the row. Between the treated sections, guard rows were left untreated. Trees of one section were left without treatment and considered as a control. Spraying was carried on by means of a motor sprayer of about 500 litres capacity and at a pressure of about 300 pounds per the square inch. Before starting the experiment, samples of infested Olive-tree leaves were picked up at random from each of the sections. Of each sample, 1000 scales distributed on both surfaces of the leaves were examined to find out the normal mortality picture. Insects were examined under the microscope after exposing its soft body. Such samples were examined before and after each treatment, and the mortality picture calculated in each case.

EXPERIMENTAL RESULTS

Results of the present experiments are summarized in Tables II, III, IV, and V

TABLE II

Effect of Parathion, Tetrax and Volk, used in Experiment I on the olive tree scale.

INSECTICIDE FORMULATION	NUMBER OF LIVING INSECTS PER 1000 SCALES		MORTALITY PERCENTAGE	REMARKS
	BEFORE SPRAYING 4.12.1952	AFTER SPRAYING 10.1.1953		
Untreated	650	630	3.0	Natural
0.01% Parathion	600	270	55.0	
0.02% Parathion	650	215	65.3	
0.04% Parathion	700	200	71.4	
0.10% Tetrax	660	300	55.0	
0.12% Tetrax	630	300	52.3	
1.75% Volk (petroleum oil)	650	320	50.7	

TABLE III

Results reached at in Experiment II where the same insecticides used in Experiment I were applied on the same plots as before.

INSECTICIDE FORMULATION	BEFORE SPRAYING 20.4.1953	AFTER SPRAYING 15.6.1953	MORTALITY PERCENTAGE	REMARKS
Untreated	650	620	4.0	Natural Crawler present
0.01% Parathion	260	130	42.3	
0.02% Parathion	220	90	58.1	
0.04% Parathion	200	70	65.0	
0.10% Tetrax	280	120	57.1	
0.12% Tetrax	300	100	66.0	
1.75% Volk (petroleum oil)	300	150	50.0	

TABLE IV

Results of Experiments I and II, showing the accumulative effect of two successive applications of each of the three insecticides.

INSECTICIDE FORMULATION	BEFORE SPRAYING 4.12.1952	AFTER SPRAYING 15.6.1953	MORTALITY PERCENTAGE	REMARKS
Untreated	650	620	4.0	Natural
0.01% Parathion	600	150	75.0	
0.02% Parathion	650	90	81.5	
0.04% Parathion	700	70	90.0	
0.10% Tetrax	660	120	78.7	
0.12% Tetrax	630	100	80.8	
1.75% Volk (petroleum oil)	650	150	69.2	

TABLE V

Effect of higher Parathion concentrations used in Experiment III for the control of the olive tree scale.

INSECTICIDE FORMULATION	NUMBER OF LIVING INSECTS PER 1000 SCALES		MORTALITY PERCENTAGE	REMARKS
	BEFORE APPLICATION 11.11.1953	AFTER APPLICATION 11.12.1953		
Untreated	800	820	—	Applied on previously sprayed plots in experi- ments I and II.
0.02% Parathion	150	70	53.3	
0.04% Parathion	120	50	58.3	
0.08% Parathion	180	45	75.0	
0.08% Parathion	750	120	84.0	Applied on a new plot.

DISCUSSION AND CONCLUSIONS

The results reached at during the present study indicate that on the whole, Parathion is more effective than both Tetrax and Volk (petroleum oil) in the control of the Olive-tree scale, *Leucaspis riccae* Targ., under conditions that prevailed during this investigation. Tetrax, being still only produced for limited experimental purposes, cannot yet be recommended for application under the present conditions. The superiority of Parathion to the petroleum oil may be attributed to many reasons most prominent among which are :

1. Differences in the nature of the compounds

The petroleum oil used in the present investigation is an emulsion containing 80 % of a refined mineral oil which consists of at least 94% of unsulphonated residues. Parathion, in contrast to petroleum oils, is a fairly pure compound. As the rest of the group of phosphorous insecticides, it has its efficiency attributed to its chemical structure.

2. Ability of the insecticide to spread within the plant tissues

Petroleum oils do not penetrate the plant tissues and are thus not transported along with the plant sap, but remain on the surface and bring their effect on insects through contact. On the other hand Parathion, being at least partially systemic, when sprayed on the trees, enters to the inner tissues and is carried along with the sap thus reaching parts that are not even directly hit by the insecticide during the spraying process. In this manner, Parathion, beside exerting a contact effect on the insects, it kills them also through feeding action. Insects sucking the plant juices suck along with them the toxin and are thus destroyed. Although the systemic nature of Parathion has been supported by many American workers, yet other substances are considered by British scientists (Ripper and others, 1950), as more valuable in this respect. Such differences in nature of these compounds, no doubt, affect their degree of penetration into the insect body and ultimately their lethal action. The following features which make Parathion considerably more efficient than petroleum oils are supplemented by other features that make it preferable also for the control of scale insects :

(1) Being effective at very low concentrations: a feature that makes the use of Parathion more economical, since it cuts down the effort, labor and expense of the control measures.

(2) Possessing no phytotoxicity at these effective low concentrations : making its application on economically important trees safe.

(3) Its partial water solubility : the insecticide being applied as a water suspension spray makes the process still easy and cheap.

(4) Having a residual effect : it remains in the plant tissues for a period that may reach up to one month (American Cynamide Co., 1948). This feature makes it possible to avoid spraying at the blossoming period, but still have insects controlled throughout the season.

From the foregoing discussion, it becomes quite obvious that Parathion is more suitable than petroleum oils and should replace them in the control of scale insects. The great efficiency of this compound warrants going through the care that should be taken during its application due to its great toxic nature, especially at its high concentrations.

(II) Parathion brings a better control picture when used at a higher concentration (0.08%) than when applied at comparatively low concentrations (0.01, 0.02, and 0.04%).

(III) Two applications of Parathion at a concentration of 0.04% brings a better control picture than one application of 0.08%, and thus the former concentration is recommended.

(IV) Consideration of the level of living insects before and after the various experiments periods indicate that the activity period of the insect (crawlers emergence period) is during the spring and early summer. The insect produces mainly a single generation per annum. The crawlers, appearing early in the season, settle down and produce their scales which are soft at first, and harden later by the end of the season (November-December). As seen from the Tables, at the end of the season the number of living insects in the untreated areas shows an increase due to the new progeny added. The number of progeny per season is enough to cover the loss caused by natural mortality, and adds moreover, to the total number of living insects.

(V) The reduction in population after a single application of the insecticides is not much. In order to bring about a good control picture, two to

TABLE VI.

A comparison between Parathion and Volk from an economic standpoint.

INFORMATIONS ABOUT	PARATHION	VOLK	REMARKS
Concentration recommended.	0.04%	1.75%	Both insecticides are recommended to be used twice or three times during the season.
Number of applications.	2	2	
Percentage insect kill attained after two treatments.	90	69.2	Tetrax is still in the experimental state and not yet put in the market
Amount of spray necessary for covering of a middle sized olive-tree (about 300 cubic feet).	5 litres	5 litres	
Amount of active ingredient entering in formation of five litres spray.	2 gms.	87.5 cc.	Prices in local market approximately and are liable to changes.
Price of amount of active ingredient necessary for making five litres spray.	1 piaster	1.75 piasters	
Cost of spraying of 100 medium sized olive trees, once.	100 piasters	175 piasters	

three applications should be tried. The most essential treatment should be applied at the time of crawlers emergence (April-June). This treatment destroys the crawlers and meanwhile kills some of the adults.

(VI) Although much precaution has to be taken in applying Parathion yet its superiority to petroleum oils, generally applied for the control of the pest under consideration, warrants going through the hazards that go with its use.

(VII) from an economic point of view, the use of Parathion is more profitable than the use of Volk, as can be grasped from Table VI.

SUMMARY

Parathion, Tetrax and Volk (petroleum oil) were tried for the control of the Olive-tree scale, *Leucaspis riccae* Targ.

At the concentrations commonly used for similar purposes and which were tried during the present work, Parathion was found more effective than both Tetrax and Volk. The superiority of this material was attributed to its chemical structure and its partial systemic nature. Other features that make Parathion preferable to petroleum oils have been discussed.

Parathion was found more effective at a concentration of 0.08% than at lower concentrations ranging between 0.01 and 0.04%. Even at this high concentration, one application of this chemical did not control the pest to an economic level. Two or three applications of the 0.04% concentration are recommended to bring about a satisfactory control picture of this insect. The application timed at the period of emergence of crawlers (April-June) is the essential one in this concern.

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LITERATURE CITED

- American Cynamide Co. (1948) : Thiophos Parathion : Physical and chemical properties (U.S. Dept. Agric., Tech. Bull. No. 2).
- American Cynamide Co. (1950). Growers handbook on Parathion insecticides (U.S. America, 24 pages).
- Bottger, G.T., Yerington, A.P., and Gertler, S.I. (1949) : Preliminary tests of synthetic organic compounds as insecticides, part VI (U.S. Dept. Agric., Bull. E. 789).
- Chapman, P. J., and Pearce, G.N. (1947) : Oil sprays (*Agr. Chemistry*, II (2)).
- Frear, D.E.H. (1948) : Chemistry of insecticides, fungicides and herbicides (D. Van Nostrand, London, 417 pages).
- Ripper, W.E., and Greenslade, R.M. (1950) : A new systemic insecticide, Bis (Bis dimethylamino phosphorous anhydride) (*Bull. Ent. Res.*, XL (4), pp. 481-501).
- Shepard, H.H. (1946) : The chemistry and toxicity of insecticides (Minnesota, 383 pages).
- Spencer, H., Osburn, M.R., and Norman, P.A. (1952) : Control of purple scale on citrus with Parathion (U.S. Dept. Agric., Circ. No. 896, pp. 1-10).
- Spencer, H., and Norman, P.A. (1953) : Control of heavy infestations of purple scales on grapefruit trees (U.S. Dept. Agric., e-870, pp. 1-5).
- Stafford, E.M. (1949) : *Four Econ. Ent.*, XLII, pp. 656-660.
- Turnipseed, G.F., and Smith, C.F. (1953) : Life-history and control of scales on apples in North Carolina (*Four Econ. Ent.*, XLVI (6), pp. 969-972).

The incidence of grasshoppers during winter months and the influence of irrigating fallow land on grasshopper population

[Orthoptera]

(with 2 Text - Figures and 2 Tables)

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CONTENTS

I. Introduction. — II. The effect of moisture on the biology of locusts and grasshoppers. — III. The incidence of grasshoppers during winter months (method of study, results). — IV. Influence of irrigating fallow land on grasshopper population. — V. Summary. — VI Acknowledgment. — VII. References.

I. INTRODUCTION

The distribution of the different species of grasshoppers does not depend on the occurrence of a certain plant species, but mostly on the abundance of grass and soil moisture. An indifferent form of grasshopper such as *Chrotogonus lugubris* Blanch., can be found everywhere, but once any part of the land is neglected and becomes covered with grass or irrigated, the population density of other geophilous species markedly increases. From these areas grasshoppers invade the adjoining cultivated lands on which they normally do not breed

It is well known that some species of Acrididae are inclined to move temporarily from one habitat into another (U v a r o v , 1928). The stimuli which initiate movement and eventually migration in locust are both ecological and physiological, but as congregation is not always a characteristic feature of grasshoppers, their wandering is almost always governed by purely ecological conditions, mainly vegetation and soil moisture. The great majority of locusts and grasshoppers lay their eggs in the ground, and the general character

of the places selected for this pupose is more or less constant for every species. But by far the most important requirement for egg-laying seems to be attached to the physical properties of the soil and above all its moisture content. When soil loses its water it becomes hard, hence a considerable difference may be observed among the different species; thus the small red-winged grasshopper *Acrotylus insubricus* Scop., can lay its eggs in almost hard soil, whereas other species such as *Aiolopus thalassinus* F., cannot penetrate such a soil. This correlates with the former being typical of drier soils while the latter is mostly associated with moist land and recently irrigated fields.

The study of the preference of each species of grasshopper for definite kind of soil moisture appears to have received insufficient attention. A part of this work was, therefore, concerned with this point; experiments were carried out in the laboratory and observations were made in the field. A detailed account of the influence of soil moisture on egg-laying behaviour will be given in another paper. The present paper gives the results of field observations which show the incidence of grasshoppers during winter months and describe the influence of irrigating fallow land on grasshopper population

II. The effect of moisture on the biology of locusts and grasshoppers

Locust and grasshoppers as well as all other terrestrial insects are apt to lose their water if subjected to dry conditions. In Egypt dry conditions are most generally encountered by terrestrial insects when winter crops are cleared off and land undergoes a prolonged period of rest. During this period grasshoppers tend to move to other habitats where food is available and air more moist.

Moisture influences the behaviour of grasshoppers in different directions and the literature abounds with such informations. It is known, for instance, that certain species of Acrididae exist in different colour forms : brown, green, reddish and striped; it was generally found that green forms are mostly associated with humid conditions. This fact was pointed out by F a u r e (1932) in the case of *Locusta pardalina* Wlk., and *Locusta migratoria migratorioides* R. and F.. Hoppers kept in isolation developed a green colour in large proportion of cases if they were kept in a moist atmosphere with plenty of green food. But if isolated hoppers were kept in a dry atmosphere, their coloration was found to be determined by that of the background. A good resemblance was obtained to a number of colours, but green could not be developed in this way. The findings of F a u r e were later confirmed by K e y (1936).

The necessity of moisture for successful embryonic and post-embryonic development has now been repeatedly emphasized. As for embryonic develop-

ment, it is well known that Acridids' eggs either shrivel up or die in dry soil or, in a certain degree of dryness, their development may be suspended for a very long time — several months — but can be resumed when an adequate amount of moisture is added to the soil (Roonwal 1936, Husain et al, 1940). The eggs of *Locusta migratoria migratorioides* R. and F., absorb water and increase considerably in weight and size. Shulov (1952) found that the average weight of *Schistocerca* egg when first laid was 10.5 mg.; when it was about to hatch, after 14 days at 27°C. and in wet sand, the average weight was 24.6 mg., a total mean increase of about 2.34 times. Salt (1949) found that the total amount of water absorbed in the eggs of the grasshopper *Melanoplus bivittatus* Say, was about 60% of the original weight of the egg; but that the greatest amount of water (88%) had been absorbed during anatrepsis.

The optimal constant relative humidity for the development of *Locusta* hoppers and for percentage of hoppers reaching the adult stage varies from 65 to 68%, depending on temperature, and for *Schistocerca* hoppers from 60 to 70%. Below and above these humidities the rate of development decreases; the decrease being much greater with a rise in humidity above the optimum range than with a reduction below it (Hamilton 1936, 1950). Hamilton also found that sexual maturation which is, of course, a necessary preliminary to oviposition, required a moderately high humidity. The optimal constant relative humidity for sexual maturation and number of egg-pods per female was 70% for *Locusta*, and between 65 and 70% for *Schistocerca*. Below and above this humidity sexual maturity was very much lengthened.

Moreover, it has been shown in various countries that oviposition occurs only after a fair amount of rain has fallen (Johnston, 1923, on *Anacridium moestum melanorhodon* Walker; Cotterell, 1931, on *Locusta migratoria migratorioides*; R. and F. Ramachandra Rao, 1934, 1942, and Maxwell Darling, 1924, 1936, on *Schistocerca*). Faure (1932) and Kennedy (1949) also found in cage experiments on *Locusta* that egg-laying occurred in wet sand and not in dry. Maxwell-Darling (1934) considered that, while the sexual maturation of *Schistocerca* is brought about by a mere rise in relative humidity, oviposition requires rainfall which moistens the sand.

Golding (1934) studied the distribution and the ecological plasticity of Acrididae near Lake Chad in the Sudan and came to the conclusion that their choice of stations for concentration appeared to be influenced by micro-climatic conditions rather than by the nature of the vegetation. He was able to show that *Aiolopus* spp., were found almost always in very wet habitats; *Acrolylus blondeli* Sauss., which is a geophilus species, was frequently found on bare soil; *Pyrgomorpha cognata* Kr., was observed ovipositing in hard bare soil; *Anacridium moestum* Serv., was normally found in tall vegetation and so

cotton fields, old maize and tall dead leguminous plants were favourite habitats. In general, the Catantopinae showed a greater degree of ecological plasticity than did any of the other subfamilies, the majority of the species encountered were most abundant in the drier habitats.

III. THE INCIDENCE OF GRASSHOPPERS DURING WINTER MONTHS

The species of Acrididae, occurring in Shebin El-Kom district, when studied in the field, do not all prove to be equally responsive to soil moisture. On resting land which undergoes a prolonged period of drought, as occurs during summer, the population density of grasshoppers comes to its minimum level and is represented by certain two or three species. But in the adjoining cultivated fields, or along the brooks where grass is usually abundant, grasshoppers occur in large numbers and the population is represented by several species. It was found that a female grasshopper cannot lay her egg in an almost dry soil, and therefore, neither egg-pods nor early nymphal stages were found on fallow or ploughed land which were kept dry for a long time.

On the Faculty's farm at Shebin El-Kom, some ten species of Acrididae are generally abundant. They are as follows :

Oedipodinae: *Aiolopus thalassinus* F., *Aiolopus savignyi* Krauss, *Acrotylus insubricus* Scop.

Acridinae: *Calephorus venustus* Walk.

Pyrgomorphinae: *Chrotogonus lugubris* Blanch., *Pyrgomorpha conica* Cl., *Paratettix meridionalis* Ramb.

Catantopinae: *Anacridium aegyptium* L., *Eupropocnemis plorans* Charp., *Thisoicetrus littoralis* Ramb.

The Faculty's farm is almost always under cultivation. The major part, 100 feddans (1 feddan = 1.038 acres), is maintained for crop production. Clover, wheat, broad beans, are produced every year and are generally planted in September or beginning of October. They are called "winter crops" as they grow during winter and are cropped in May or June. Maize generally follows, but a certain part of the land is kept fallow till one of the winter crops is planted again. Cotton is generally set at the beginning of March, it is planted in the resting land cropped the previous year and which is kept dry for a prolonged period throughout the summer and early winter. The amount of rain which falls every winter is very slight, and watering is dependent on irrigation. A second, but smaller part of the Faculty's farm, is used for horticulture : 11 feddans for citrus and different deciduous trees, 3 feddans for the production of truck crops, and 3 feddans for floricultural purposes.

At any time of the year this farm, as it appears, contains different sorts

of plants and crops. Grasshoppers do not usually occur in thick and dense cultivation, but they are generally found in fields in which seedlings of wheat or clover are just growing, and neglected areas covered with grass.

Method of study

Methods of estimating the relative abundance of grasshoppers present many great practical difficulties owing to their extremely active movement. Golding (1934) collected, during a period of 15 minutes, the Acridids occurring in six collecting areas. Ten trained boys were able to capture the majority of Acridid population. The abundance of each species was expressed as a percentage of the catch, so if a particular species occurred in 10 out of 20 catches, its frequency would be 50%. He also found that it was essential to carry out the collecting before the commencement of activity which usually started early in the morning. Joyce (1952), in his study of grasshopper fauna in East Central Sudan, commented on two methods of estimating grasshopper numbers, namely, counting disturbed insects in a walk over a measured distance, and catching samples. Counting disturbed insects was found very unreliable as the activity of grasshoppers was much affected by temperature and humidity, and because of certain species hid in soil cracks or under vegetation that it was impossible to see any which were disturbed. Moreover, counting disturbed grasshoppers, tended to exaggerate the numbers of the species which were generally active flyers.

Estimating the numbers by catching, also suffered from some disadvantages as insects in dense vegetation were less available than in open vegetation. Moreover, the personal element was of great importance, as some boys who were collecting, tired very rapidly. Richards (1953) gave recommendation on the methods of estimating the numbers of adult Red Locust, *Nomadacris septemfasciata* Serville, in Tanganyika. He stated that the two principal methods are : scouting, this is counting the number of locusts flushed per hundred paces; and marking, releasing and recapturing locusts. It was also pointed out that in high concentrations of locusts the scouting method breaks down.

No attempt was undertaken to ascertain the grasshopper population in the Faculty's farm, but it was intended to study the relative abundance of the different species of grasshoppers using the method of catching. This method proved satisfactory under our condition as the difficulties pointed out by Joyce were eliminated. Two trained boys were employed, each making one separate catch every day for an hour. Nets were used and the collecting area was swept daily. The personal element was undoubtedly still existing as the time allowed for catching per month and even per day was not strictly kept and one could not make sure that the boys were engaged

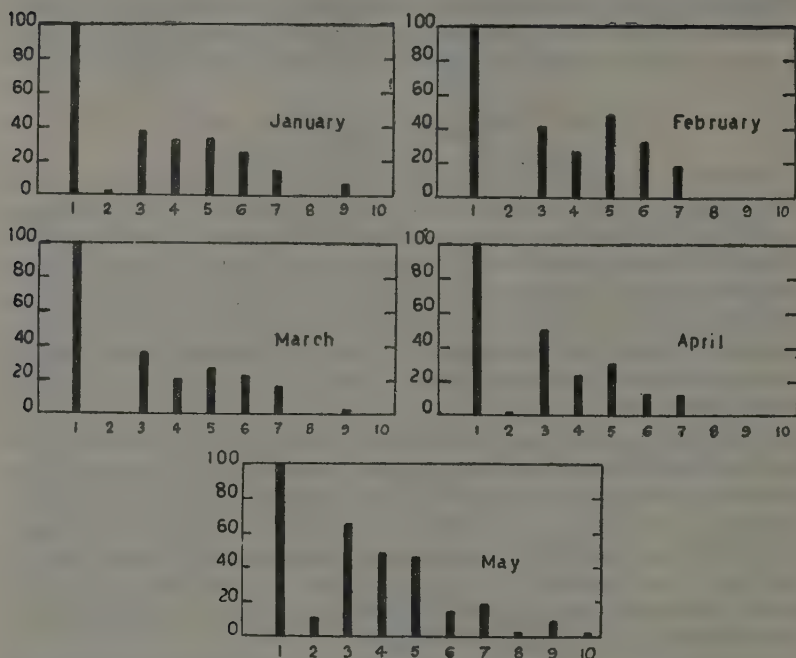


Fig. 1: The relative abundance of the different species of grasshoppers from January to May 1953 (1. *A. thalassinus*, 2. *A. savignyi*, 3. *Acrotylus insubricus*, 4. *Calephorus venustus*, 5. *Chrotogonus lugubris*, 6. *Pyrgomorpha conica*, 7. *Paralettix meridionalis*, 8. *Euprepocnemis plorans*, 9. *Thisoicetrus littoralis*, 10. *Anacridium aegyptium*). — Ordinate : index of abundance.

all the time in collecting. Therefore, the catches were by no means a measure of the population, but gave a mere comparison between the specific population during winter months and spring. Analysis of insects caught was regularly made from the beginning of January till the end of May, 1953. Then catching was unavoidably interrupted because one of the boys was removed and the other engaged in some other work, but he resumed the same work between November 1953 and January 1954. The data of May 1953 would give an approximate idea of the grasshopper fauna of the District in the following summer. Index of abundance is obtained by denoting the catch of *A. thalassinus* which is the most abundant grasshopper, as 100, and reducing the catch of every other species accordingly ; this is shown graphically in Figure 1.

Results

It can be observed that the species which do not go into hibernation, as all stages can be found during the winter months, are: *A. thalassinus*, *Acrotylus insubricus*, *Calephorus venustus*, *Chrotogonus lugubris*, *Pyrgomorpha conica*, and *Paratettix meridionalis*. The adults and hoppers of *Aiolopus savignyi* undergo heavy mortality with the approach of winter, and hibernation takes place in the egg-stage. Very few adults were caught during January, none in February and March. It reappeared in April and a considerable increase occurred in May. The five males recorded for April were caught between 28th and 30th of that month; they were undoubtedly the early adults of the first generation of that season. *Euprepocnemis plorans* undergoes a similar behaviour. Adults and hoppers usually die towards the end of autumn and their number declines rapidly in November. In November 1953, 4 males, 3 females and no hoppers were caught, whereas they were fairly abundant in October and the previous summer months. The appearance of hoppers in May marks the beginning of the first generation. *Euprepocnemis* goes into a state of egg-diapause during winter. Laboratory study has shown that egg-pods are generally laid in July and August, some of the eggs hatch and give rise to a second generation, the others as well as most of the eggs of the second generation go into diapause till next May when they usually hatch. In the Sudan, *Euprepocnemis ibandana* Giglio-Tos and *E. noxius* Dirsh, breed continuously throughout the year, and there is no diapause in any stage (Joyce, 1952).

Few adults of *Thisioicetrus littoralis* were caught over the period from January to April and this indicates that hibernation occurs in the adult stage. But its eggs do not hatch during winter if kept under normal conditions. But if transferred to 25°C. some complete development and hatch, while others remain in a state of diapause for several months. Therefore, it can be stated that hibernation occurs in the adult and egg-stage, and that some eggs undergo a prolonged period of embryonic diapause. As for *Anacridium aegyptium*, it has been found that hibernation occurs in the adult stage.

During summer all species, the non-hibernating, the hibernating, and those which go into diapause, increase considerably in number with *A. thalassinus* still having the highest population. Adults of *E. plorans* were collected in the field in June 1953, and these were the earliest individuals of the first generation. Adults live fairly long, those which emerged in the experimental cages lived a little more than three months. In the field the highest population of adults was encountered in September and October, and those must be the imagoes of the first and second generations. It declined in number at the middle of November and in December 1953, when only 4 males and 3 females were caught; in the laboratory all adults died by the 23rd of December. On

4th January 1954, one nymph was caught. This and most likely many others, as laboratory study have shown, must have emerged from non-diapause eggs. They do not survive the winter and will certainly perish later in January.

During summer, *A. savignyi* increases considerably in number and stands next or very close to *A. thalassinus* in order of abundance. It declines in November and very few adults can be caught in December. In January 1954, only one male was caught. In May 1953, several nymphs of *Thisoicetrus* made their appearance. It increases in number in the following summer months and attains its highest level in August. But it remains, nevertheless, not very common. It can be stated that *Thisoicetrus littoralis* and *Anacridium aegyptium* are the least abundant Acridids in Shebin El-Kom, other Acridids can be considered rare.

A. savignyi has a wide world distribution. It occurs in several parts of Africa and western Asia, and it is the most important grasshopper in East Central Sudan (Joyce, 1952). It is the opinion of this author that *A. savignyi* has the potentiality of becoming, as agricultural development in Africa expands, a very serious pest. In the Sudan it survives the winter, which is the dry season, inactive hiding in soil cracks. There, winter conditions are less severe as meteorological records at Jebel Ghadambaliya during 1948 show that during December and January the maximum temperature ranges between 34 and 36°C., and the minimum temperature between 12 and 17°C. In the cracked soil of the Sudan, temperature at 2 feet depth is fairly steady at 27°C., and the air within the small cracks is practically saturated with moisture. The cracks are also a favoured refuge for other species of grasshoppers such as *Euprepocnemis noxius*, *Pyrgomorpha kraussi*, *Acrotylus blondeli* and *A. patruelis*. Moreover, it has been stated by the same author that *Pyrgomorpha cognata* and *Chrotogonus* sp., breed throughout the year, but *Thisoicetrus leani* survives the dry season in the egg stage.

In winter, save the resting part of the Farm which is being prepared for the production of cotton, most of the land is under cultivation, and therefore, soil cracks will not serve as a refuge for the hibernating grasshoppers. Moreover, in December and January air temperature is usually lower than what is recorded in the Sudan. The sun maximum temperature ranges between 15 and 30°C., and the minimum temperature between 8 and 16°C. In the shade, among the grass where grasshoppers usually move, and in the soil which is watered very often and in which egg-pods are deposited, temperature range is closer and its limits are very much lower. Degrees near the freezing points (3-5°C.) were recorded in our district on several occasions, and the sun maximum temperature mentioned above was never recorded in the soil (vide McKenzie-Taylor and Williams, 1924). So it is clear that our meteorological conditions are quite different from those of the

Sudan, and therefore, differences in the ecology of grasshoppers, especially in the way they pass the cold season, is expected.

IV. INFLUENCE OF IRRIGATING FALLOW LAND ON GRASSHOPPER POPULATION

When winter crops are cleared in May or June, a certain period elapses before the land is ready for the cultivation of maize, one of the winter crops, or cotton. Thus the land is left resting for a varying length of time ranging between one and several months, during which period air temperature may rise to a very high level (47°C ., measured by a white bulb thermometer) and the relative humidity goes down to 36.5% (July, 1952). The soil surface temperature may even reach a higher level, 65°C ., was recorded by Mc-Kenzie and Williams at Giza, and the maximum sun temperature they recorded, using a black bulb thermometer, was 74.4°C . Thus it appears that the saturation deficit in our district is very high (it may reach up to 25 or 30 mm. in the hottest part of the day) and the soil is apt to lose its moisture content.

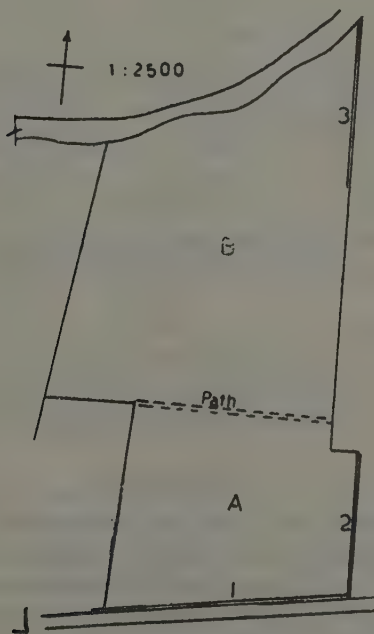


Fig. 2: The observation area where the population density of grasshoppers was studied.

An attempt was undertaken to compare the grasshopper population under such dry conditions with that found on the same fallow land but after irrigation; the influence of vegetation being thus eliminated. In August and September 1952, observations were carried out in an area of about $16\frac{3}{4}$ feddans (Fig. 2) which was left fallow since May when broad beans was cropped. A narrow path divided the area into two unequal parts, A and B. Two narrow brooks (Nos. 1 and 2) were running along the south and east of the first area, and the grass along these streams was abundant. Maize and cotton was still growing in the adjoining fields to the east and west. A narrow stream (No. 3) was running in between area (B) and the adjoining maize field lying north east.

For the purpose of comparing grasshopper population three boys were employed (Sh, Z, and S), each starting from the centre of each area makes two separate catches, each of 15 minutes. Boys were walking in different directions and when the time ended they returned to the centre and each catch was analysed on the spot as insects were set free from the collecting jars. Following the same procedure, collecting was also carried out on fallow land but along streams (Nos. 2 and 3) and the adjoining newly irrigated field of maize lying south west of area (B) where grass was abundant and land

TABLE I

Number of grasshoppers (including adults and hoppers) caught in six catches, in a stretch 10 metres wide, along streams and newly irrigated field of maize. — Grass was abundant and land moist.

SPECIES	ALONG STREAM No. 2		ALONG STREAM No. 3	NEAR NEWLY IRRIGATED FIELD OF MAIZE
	COLLECTING 27.9.1952	COLLECTING 5.10.1952	COLLECTING 8.10.1952	COLLECTING 30.9.1952
<i>Aiolopus savignyi</i>	45	67	129	83
<i>Aiolopus thalassinus</i>	15	35	31	16
<i>Pyrgomorpha conica</i>	—	—	—	2
<i>Chrotogonus lugubris</i>	4	6	7	8
TOTAL	64	108	167	109
MEAN PER CATCH	10.7	18	27.8	18.2
MEAN OF MEANS	18.5			

almost moist by infiltration. The analysis of capture is shown in Table I. On 9.x.1952, the western half of area (A) was irrigated, and on 18.x.1952 when this part was muddy and the other part still fallow, counting was carried out on both areas. Similarly, on 29.x.1952 a major part of area (B) was irrigated, and on 5.xi.1952 counting was carried out on both irrigated land and fallow. On that date only one catch was made by the collectors. The analysis of capture is shown in Table II.

TABLE II
The population density of grasshoppers caught in 15 minutes,
on irrigated and fallow land.

SPECIES	IRRIGATED LAND		FALLOW LAND	
	AREA (A) PART IRRIGATED 9.10.1952 COLLECTING 18.10.1952 NUMBER CAUGHT IN 6 CATCHES	AREA (B) PART IRRIGATED 29.10.1952 COLLECTING 5.11.1952 NUMBER CAUGHT IN 3 CATCHES	AREA (A) COLLECTING 18.10.1952 NUMBER CAUGHT IN 6 CATCHES	AREA (B) COLLECTING 5.11.1952 NUMBER CAUGHT IN 3 CATCHES
<i>Aiolopus savignyi</i>	122	79	43	3
<i>Aiolopus thalassinus</i>	10	5	2	—
<i>Pyrgomorpha conica</i>	—	1	1	1
<i>Chrotogonus lugubris</i>	5	2	3	3
TOTAL	137	87	49	35
MEAN PER CATCH	22.8	29	8.2	11.7
MEAN OF MEANS	25.9		9.9	

It can be observed that among the species of grasshoppers found in our district only four were present on such clear uncultivated land. *A. savignyi* was always the most abundant. *A. thalassinus* was almost absent on fallow land but present in considerable number along streams, canal banks and near irrigated fields where grass was abundant and land moist (Tables I and II); the number caught was 21.6% of the total catch. *C. lugubris* had a higher density on fallow than on irrigated fields, the numbers caught were 7.2 and 3.1% of the total catch, respectively (Table II). Along streams and newly irrigated fields, it was 5.6% of the total catch. Thus, it appears that *C. lugubris* seems to be a species of great plasticity, having no definite preference to a particular habitat. *P. conica* was the least abundant on fallow, irrigated fields and along streams. Nearly the same percentage of the total catch was found on the different observation areas.

There was a considerable increase in the population density of grasshoppers when fallow land was irrigated (Table II). It was 2.6 times that on fallow land. This increase was mostly due to the immigration of *A. savignyi* and *A. thalassinus* from the adjoining cultivated fields.

V. SUMMARY

Field study has shown that the species of grasshoppers found in our district fall into two categories : one breeds continuously throughout the year, and the other goes into a state of diapause.

Aiolopus thalassinus, *Acrotylus insubricus*, *Calephorus venustus*, *Chrotogonus lugubris*, *Pyrgomorpha conica* and *Paratettix meridionalis* belong to the first group. *Euprepocnemis plorans* and *Thisoicetrus littoralis* belong to the second group.

There is a third group which goes into hibernation during winter; this is represented by *Aiolopus savignyi* which pass the winter in the egg-stage.

The population density of grasshoppers increases on fallow land when irrigated. This increase is due to the immigration of *A. savignyi* and *A. thalassinus* from the adjoining cultivated fields.

Along streams and on land covered with tall grass the population is always higher than on bare or cultivated areas.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

- Ballard, E., Mistikawi, A.M., and Zoheiry, M.S. (1932): The desert Locust, *Schistocerca gregaria* Forsk, in Egypt (Technical and Scientific Service, Bulletin No. 110, Ministry of Agriculture, Cairo).
- Cotterell, G.S. (1931): The occurrence of the migratory locust (*Locusta migratoria migratorioides*) in the Gold Coast and its dependencies during 1930 (*Bull. Dept. Agric. Gold Coast*, XXIII, pp. 255-281).
- Faure, J.C. (1932): The phases of Locusts in South Africa (*Bull. Ent. Res.*, XXIII, pp. 293-424).
- Gause, G.F. (1930): Studies on the ecology of the Orthoptera (*Ecology*, XI).
- Golding, F.D. (1934): On the ecology of Acrididae near lake Chad (*Bull. Ent. Res.*, XXV, pp. 263-303).
- Hamilton, A.G. (1936): The relation of humidity and temperature to the development of three species of African locusts: *Locusta migratoria migratorioides*, *Schistocerca gregaria*, *Nomadacris septemfasciata* (*Trans. R. ent. Soc. London*, LXXXV, pp. 1-60).
- Hamilton, A.G. (1950): Further studies on the relation of humidity and temperature to the development of two species of African locusts; *Locusta migratoria migratorioides* and *Schistocerca gregaria* (*Trans. R. ent. Soc. London*, CI, pp. 1-58).
- Husain, M.A., Ahmad, T., and Mathur, C.B. (1940): Studies on *Schistocerca gregaria*. V. Role of water in the bionomics of the Desert Locust (*Indian J. agric. Sci.*, X, pp. 927-944).
- Johnston, H.B. (1923): A note on locusts (*Sudan Notes and Records*, VII, pp. 91-101).
- Joyce, R. J. V. (1952): The ecology of grasshoppers in East Central Sudan (*Anti-Locust Bulletin*, 11).

- Kennedy, J.S. (1939) : The behaviour of the Desert Locust (*Schistocerca gregaria*) in an outbreak centre (*Trans. R. ent. Soc. Lond.*, CXXXIX, pp. 385-542).
- Kennedy, J.S. (1949) : A preliminary analysis of oviposition behaviour by *Locusta* in relation to moisture (*Proc. R. ent. Soc. Lond. (A)*, XXIV, pp. 83-89).
- Key, K.H.L. (1936) : Experimental studies on locomotor activity in *Locusta m. migratorioides* (*Bull. ent. Res.*, XXVII, pp. 399-422).
- Maxwell-Darling, R.C. (1934) : The solitary phase of *Schistocerca gregaria* in North-eastern Kordofan (*Bull. ent. Res.*, XXV, pp. 63-83).
- Maxwell-Darling, R.C. (1936) : The outbreak centres of *Schistocerca gregaria* on the Red Sea Coast of the Sudan (*Bull. ent. Res.*, XXVII, pp. 37-66).
- McKenzie-Taylor, E., and Williams, C.B. (1924) : A comparison of sand and soil temperatures in Egypt (Ministry of Agriculture, Technical and Scientific Service, Bull. No. 40, Cairo).
- Ramachandra Rao, Y. (1934) : The life-cycle, particularly sexual maturation, in relation to climate and other factors and methods of (*Proc. Third Int. Locust Conf., London*).
- Ramachandra Rao, Y. (1942) : Some results of studies on the desert locust in India (*Bull. ent. Res.*, XXXIII, pp. 241-265).
- Richards, O. W. (1953) : The study of the numbers of the Red Locust (*Anti-Locust Bull.*, 15).
- Roonwall, M.L. (1936) : The growth-changes and structure of the egg of the African migratory locust, *Locusta m. migratorioides* (*Bull. ent. Res.*, XXVII, pp. 1-14).
- Rubtsov, L.A. (1935) : Phase variation in non-swarming grasshoppers (*Bull. ent. Res.*, XXVI, pp. 499-524).
- Rubtsov, L.A. (1934) : Fertility and climatic adaptation in Siberian grasshoppers (*Bull. ent. Res.*, XXV, pp. 339-349).
- Salt, R.W. (1949) : Water uptake in the eggs of *Melanoplus bivittatus* (*Canad. J. Res.*, D, XXVII, pp. 236-242).
- Shulov, A. (1952) : The development of eggs of *Schistocerca gregaria* in relation to water (*Bull. ent. Res.*, XLIII, pp. 469-476).
- Uvarov, B.P. (1928) : Locusts and grasshoppers (London).
- Waloff, N. (1950) : The egg pods of British short-horned grasshoppers (*Proc. R. ent. Soc. Lond. (A)*, XXV, pp. 115-126).

Biological studies on *Bruchidius trifolii* (Motsch.) and *Bruchidius alfieri* Pic, in Egypt

[Coleoptera : Bruchidae]

(with 37 Text-Figures and 6 Tables)

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I. INTRODUCTION

The Egyptian clover, *Trifolium alexandrinum* (commonly known as berseem) is one of the most important crops in Egypt. Its economic importance comes from the fact that the green plant is the principal food for cattle, sheep, some domestic animals, etc., during a great part of the year, from December to June. It is also a very valuable cover crop for enriching the soil.

The berseem seed beetles, *Bruchidius trifolii* and *Bruchidius alfieri*, cause serious damage to the seeds by the feeding of the larva which passes all its life aside the seed, consuming all its contents and rendering it unfit for sowing.

Infestation begins in the field when the berseem plant is blooming and beginning to produce seeds. This infestation continues for several generations in storage. The injury may not be noted at harvest time, but is usually noted after the crop has been stored in the warehouse.

Owing to the serious damage bruchid beetles cause to the seeds of a great variety of plants, studies on their biology have received the attention

of a number of workers, notably Riley and Howard (1892), Chittenden (1898), Razzauti (1917), Kunhi Kannan (1919 and 1923), Paddock and Reinhard (1919), Marcucci (1920), Larson and Simmons (1923), Larson and Fisher (1924 and 1938), Skaife (1926), Zacher (1928 and 1930), Brindley (1933), Menusan (1934, 1935, and 1936), Herford (1935), Larson, Brindley and Hinman (1938), Back (1940), Bushnell and Boughton (1940), Schoof (1941), Steffan (1945), Zaazou (1948), Vukasovitch (1949), Brindley and Chamberlin (1952), Hafez and Osman (1954), Abou-Raya (1954), and others.

In spite of the fact that *Bruchidius trifolii* and *Bruchidius alferii* are pests of berseem in Egypt and cause considerable damage to the seeds, no detailed study of their biology has been previously carried out. A short note on the biology and control of *Bruchidius trifolii* was given by Willcocks (1922), but all his information on the biology was based on mere assumptions as he was not certain of the life-history of the insect. More recently (January 1954), the present authors published a note on the biology of *Bruchidius trifolii* and *B. alferii* in which they proved by experimental evidence that they are two forms of one and the same species. A similar conclusion was arrived at later by Abou-Raya (June 1954).

With such inadequate knowledge of this insect pest, it was found advisable that a detailed investigation into its biology be undertaken in the department of Entomology, Faculty of Science, University of Cairo, in order to work out such points as the life-cycle, number of generations, etc., of both forms, and to find which of them is the more common.

The authors wish to express their sincere thanks to Professor H.C. Efflatoun, former head of the Department of Entomology, and to Professor Dr. H. Priesner, for their valuable suggestions and criticism. The junior author is greatly indebted to Mr. Rizk Attia, Entomological Section, Ministry of Agriculture, and to Mr. A. Alfieri, General Secretary of the Entomological Society of Egypt, for their kind help and advice.

II. NOMENCLATURE AND DESCRIPTION

The family *Bruchidae* has also been known under two other names, the *Mylabridae* and the *Lariidae*. It is divided into a number of sub-families, of which the *Bruchinae* contains the genus *Bruchidius* (formerly considered as a sub-genus by some authors).

Bruchidius trifolii (Motsch.) has been recorded under two other generic names: *Bruchus trifolii* Motsch. (1873), and *Mylabris trifolii* Baudi (1886 and 1887).

Bruchidius alfieri, on the other hand, has been first described by Pic (1922) under the name *Bruchus* (*Bruchidius*) *alfieri*.



Fig. 1 : *Bruchidius trifolii* (Motsch.) and *alfieri* Pic, adult.

The adult of both *trifolii* and *alfieri* (Fig. 1) is 1.4 - 2.2 mm. in length and 0.8 - 1.1 mm. in breadth. It possesses more or less serrate antennae which are longer in the male than in the female. The prothorax has regular margins and the elytra are truncate. The hind femur possesses a very small tooth on its inner side (this tooth was overlooked by Motschulsky (1873) in his original description of *B. trifolii*, but later Schilsky (1905) emphasized its presence.

The general colour of the body is black and is densely covered with grey pubescence except for the middle part of the base of the pronotum, the scutellum and four patches on the elytra which are covered with white pubescence. These patches are more distinct in *Bruchidius trifolii* than in *B. alfieri*.

B. trifolii is easily distinguished from *B. alfieri* by the colour of its legs and antennae, which are black in *trifolii* and more or less ferruginous in *alfieri*.

III. GEOGRAPHICAL DISTRIBUTION

The berseem seed beetles, *Bruchidius trifolii* (Motsch.) and *Bruchidius alfieri* Pic, are only restricted to very few particular areas. Motschulsky (1873-74) recorded his *Bruchidius trifolii* from Carniolia (Yugoslavia). Baudi (1887) noted that this insect was imported in great numbers with seeds of *Trifolium pratense* from Egypt to Erlangen (Germany). Schilsky (1905) states that "Mr. U. Sahlb erg repeatedly found this species on

his journey to Egypt (Cairo, Helouan, Heliopolis, Fajoum)". It has also been reported from Egypt by Willcocks (1922).

From the literature available to the writers, it seems that *Bruchidius alferii* Pic has been only recorded from Egypt.

IV. MATERIAL AND TECHNIQUE

The insects used in the course of the present work were taken from a stock kept at 32°C. and 50% R.H. and reared on berseem seeds (*Trifolium alexandrinum*). This stock was started from insects collected by sweeping over the berseem plant during April and May. The adults were taken within twelve hours after emergence. The effect of the different factors, i.e. temperature, humidity, food, mating, repeated copulation and delayed fertilization, on the various life processes of the insect was studied.

The effect of four temperatures, namely 32, 28, 23 and 16°C., was tested. This was carried out in incubators kept at these constant temperatures. The effect of four relative humidities, viz. 30, 50, 70 and 90% R.H., was also tested at each of these four temperatures. 100% R.H. was not used owing to the rapid development of fungi on the seeds at this very high humidity. For the control of humidity, desiccators with well fitted and greased lids were used. Each desiccator contained at the bottom about 200 cc. of potassium hydroxide solution of such concentration as to give the desired humidity. These solutions were prepared according to Buxton and Mellanby (1934), and Solomon (1951). Their specific gravity was measured by means of Gallenkamp's hydrometers, and the relative humidities were checked before use by a hair hygrometer. Potassium hydroxide solutions were chosen for the control of humidity in order to absorb any CO₂ produced by the seeds as the accumulation of this gas in the desiccators may have an influence on the insects.

The seeds used in all the breeding experiments were previously heated at 70°C. for few hours and then kept in shallow layers at the required temperature and humidity for about three weeks to be conditioned.

For studying the morphology of the immature stages, the seeds were soaked for sometime in water till the seed coat became soft enough and then the larvae or pupae were taken out. Measurements of all the developmental stages as well as of the head capsule of the different larval instars were carried out. Permanent preparations of the head and mouth-parts of all the larval instars were made using acid fuchsin as a stain. The first larval instar was studied from permanent preparations while the other larval and pupal instars were examined from specimens kept in 70% alcohol, since in stained preparations the body sutures of these latters became indistinct.

All drawings were made with the aid of the camera lucida.

V. BIONOMICS AND LIFE-HISTORY

1. Seasonal abundance

Berseem seeds (Egyptian clover) are sown in Egypt during September, October and November. Two kinds of berseem are cultivated, the multi-cutting berseem or "Miskawi" and the uni-cutting or "Fahl". The former variety is largely grown in Lower Egypt whereas a large amount of the latter is grown in Upper Egypt and rarely in Lower Egypt. The plant in the multi-cutting berseem, as its name indicates, is cut several times and fed off by cattle before setting it for seed. It is usually harvested during May and June depending on the time of the last cut preceding flowering for seed. On the contrary, the uni-cutting berseem is allowed to go to seed at a much earlier date. It is harvested in March and April.

The records obtained by the present authors on the seasonal prevalence of the berseem seed beetles are all from Giza and Lower Egypt. Sweepings were made over the berseem plant from November to late June. During the period from November to February, i.e. during the coldest times of the year, adults of *Bruchidius trifolii* only are found in the field where they are in a state of hibernation. They remain hidden under fallen leaves or any other shelter. By the beginning of March they begin to be active and fly about over the berseem plant which is in blossom and often visiting the flowers of wheat. An enormous amount was collected by sweeping over the awns of wheat in the vicinity of a berseem field from which the plant was cut off for feeding sheep and cattle. Few specimens were collected by sweeping over the blooming plants of the broad bean (*Vicia faba*) and the fenugreek (*Trigonella foenum graecum*). In April, when the berseem plant is blooming, swarms of *Bruchidius trifolii* were obtained. At the beginning of May nearly all the specimens collected were *trifolii*, while by the end of that month *alfieri* began to appear. A month later, i.e. towards the middle of June when the berseem plant has formed seeds, huge numbers of *alfieri* and very few of *trifolii* were collected.

An amount of berseem seeds was brought from Zagazig (Lower Egypt) after harvesting the crop. This was kept in the laboratory under natural conditions till the next year, with the object of observing the successive breeding of the berseem seed beetles under conditions corresponding closely to those prevailing in the store. This sample was found to contain both *B. alfieri* and *B. trifolii*, the number of individuals of the former form greatly exceeded the later. Breeding took place successfully during the summer season, i.e. from June to October, eggs were laid by females of *B. alfieri* (no eggs were laid by the *trifolii* form since sexual maturity was not reached in the laboratory as will be pointed out later) and 4 to 5 generations were produced till the beginning of October. *B. alfieri* greatly exceeded *B. trifolii* during July and

August, while the reverse took place towards September, and in the beginning of October the *alfierii* entirely disappeared. This was confirmed by examining an infested sample of berseem seeds brought from a warehouse in Shebin El-Kanater (Lower Egypt) during December, when all the live specimens included in this sample were of the *trifolii* form.

It has been observed that adults of *Bruchidius alferii* emerge from the seeds as soon as they reach the adult stage. On the contrary, most of the adults of *B. trifolii* pass the summer season in a state of aestivation inside the seed. Beetles of this latter form emerge in small numbers from time to time during the summer, but when the infested seeds are sown in September or October, the seed coat becomes softened by the irrigation water and the beetles issue in swarms. These pass the cold winter time in a state of hibernation and carry out the infestation of the new crop in the field during April and May. These observations about the aestivation and hibernation of *B. trifolii* are the same as those reported by Willcocks (1922). Willcocks and Bahgat (1937) recorded the presence of *B. trifolii* resting on cotton; and in the winter time sheltering in the old bolls, etc., of still standing cotton plants. In the laboratory, adults of *B. trifolii* can be forced to emerge by placing the infested seeds over a moistened piece of filter paper; but if it happens that those seeds containing *B. trifolii* inside them are not sown and left over the winter till the next summer, the beetles still inside the seeds fail to emerge and die.

All these observations indicate that *B. alferii* carries out the infestation in the store after harvesting the crop whereas *B. trifolii* is responsible for the infestation of the crop in the field. Also there are 4-5 generations of *B. alferii* and one generation only of *B. trifolii* throughout the year.

It is now evident that infested seeds sown in September to November are the primary source of infestation from which adults of *B. trifolii* issue and hibernate during the winter, then infesting the new crop in the field. The early maturing crops may act as secondary source of infestation since the adults emerging from their seeds due to the action of primary infestation can affect the berseem plant still in blossom. This may account for the presence of both forms in the field by the end of May.

2. Host plants

Berseem seeds are the principal host of *Bruchidius trifolii* and *B. alferii* in Egypt. Willcocks (1922), speaking of *B. trifolii*, states that "it is possible, however, that this bruchid is able to develop in the seeds of the wild clover and clover-like plants". An attempt was made to breed *B. alferii* on a variety of seeds of leguminous plants acting as hosts for other bruchid beetles.

Adults of *B. alferii* were allowed to lay eggs on the seeds of the following plants : *Vicia faba* (broad bean), *Vigna sinensis* (Chinese or black-eyed peas),

Phaseolus vulgaris (common French or haricot bean), *Lupinus termis* (lupine), and lentils. These were kept at 32°C. and 50% R.H. The eggs were laid and cemented to the seed coats as usual and on hatching the larvae bored directly into the seeds, but they were not able to continue development and in no case did the small larva develop to any appreciable extent before dying. This indicated that *B. trifolii* and *B. alferii* seem to confine their attack to the berseem seeds.

3. Breeding experiments

Males and females of *Bruchidius trifolii* and *B. alferii* can be separated easily in the living state on account of the differences in the antennae of both sexes. The antennae of the male are considerably longer than those of the female. Differences also exist in the last visible abdominal sternite or hypopygium; this is deeply emarginate in the male and much less so in the female. This last difference is not easily detected in the living state owing to the dark pigmentation of the integument and hence it is not commonly made use of in separating both sexes.

(a) Breeding *Bruchidius trifolii*

A trial was made to breed *B. trifolii* in the laboratory. Adults of this form emerging at 32°C. and 50% R.H. were separated in pairs. Each pair consisting of one male and one female, was placed in a 2 × 0.7" specimen tube together with an amount of berseem seeds and kept also at 32°C. and 50% R.H. The longevity ranged from 14 to 29 days (with an average of 21 ± 1.01 days) in the female, and from 7 to 25 days (with an average of 17.11 ± 1.21 days) in the male. As already noted, copulation was not observed in this form and no eggs were laid throughout life. Similar observations were recorded by the present authors (1954) and A b o u - R a y a (1954). The latter author, however, mentioned that in one case copulation took place between a male and a female *trifolii* emerging in the store, and an offspring was produced.

Some adults of *B. trifolii* collected from the field at the end of May were kept in a fruit jar with an amount of berseem seeds to lay eggs on. Few eggs were obtained which developed to the *alferii* form. A b o u - R a y a (1954) found that the offspring of *B. trifolii* swept during April consisted of both *alferii* and *trifolii*, the former being the majority.

(b) Breeding *Bruchidius alferii*

B. alferii was bred continuously very easily in an incubator kept at a constant temperature of 32°C. and a relative humidity of 50%. Copulation took place soon after emergence as stated before, and the females laid their

eggs on the berseem seeds. The larva, on hatching, bores directly into the seed from the egg, and all the immature stages are spent inside the seed, till they emerge as adults.

The progeny of the adults of *B. alfieri* brought from the field during June consisted of both *alfieri* and *trifolii*. By breeding *B. alfieri* for 2 or 3 generations at 32°C., the resulting offspring consisted of both forms or of one form only. But by the continuous breeding of *B. alfieri* at 32°C. for a period of about two years, there was hardly any *trifolii* produced, only the *alfieri* form was available.

During August, some adults of *B. alfieri* were taken from a stock kept for three generations at 32°C. and 50% R.H. after being collected from the field. These were separated in pairs with berseem seeds and left under natural summer conditions (28-31°C. and 30-61% R.H.) Their offspring were recorded. It was found to consist either of *alfieri* or of *alfieri* and *trifolii*.

The production of *alfieri* and *trifolii* from eggs laid by the females of either form lend support to the view previously expressed by the present authors (1954), that both forms belong to one and the same species.

(c) *Breeding intermediate forms*

It has been found that the offspring resulting from breeding at 32°C. contained besides *B. alfieri* and *B. trifolii* adults which were intermediate in their colour characteristics between both forms. For instance, some possessed black antennae (*trifolii* characteristic) and ferruginous legs (*alfieri* characteristic), others had the distal segments of their antennae and legs blackish. These intermediate forms are exactly similar to *B. alfieri* as regards sexual maturity, egg laying and other life processes, and can mate either with themselves or with *B. alfieri*.

(d) *Cross breeding*

Trials to breed males of *alfieri* with females of *trifolii* emerging at 32°C. and 50% R.H. ended in vain since these latter were sexually immature. A similar observation was reported by A b o u - R a y a (1954), although he observed in one case only copulation between a female *trifolii* and a male *alfieri* both emerging in the store and producing some *trifolii* individuals.

In the course of the present work, a male *trifolii* copulated with a female *alfieri*, both emerging at 32°C. and 50% R.H. They were kept in a 20×7" specimen tube together with 50 berseem seeds. The female laid fertile eggs. In this particular case, the length of life was five days for the female and 11 days for the male. The female laid 46 eggs during its whole life. The resulting offspring consisted wholly of the *alfieri* form, ten males and ten females were produced. This result was previously reported by the present authors

(January 1954) as a further evidence that both *alfierii* and *trifolii* are not two separate species.

It is, therefore, clear that very few individuals of *trifolii* emerging in the store during summer, are sexually mature.

4. Emergence

When ready to emerge, the adult gnaws by its mandibles a neat circular incision in the seed coat, and then pushes this incised area or disc by its head, thus forming an exactly circular exit hole through which it comes out (Figs. 2 and 3). Sometimes, the disc is pushed completely away from the seed by the head of the beetle, or it is merely pushed out like a trap door and after emergence it may swing back and close the exit hole (Fig. 3).

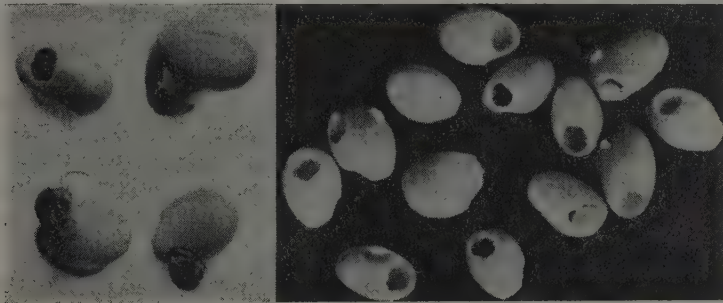


Fig. 2 : Adults of *B. alfierii* emerging from the berseem seeds. — Fig. 3 : Exit holes made by the adults of *B. alfierii* in the berseem seeds.

A single adult emerges from each seed although several larvae may enter it, but owing to the relatively small size of the berseem seed, only a single larva can continue development at the expense of the others consuming all the contents of the seed. This is in accordance with the observations of the present authors (1954) and A b c u - R a y a (1954).

5. Sex ratio and sexual maturity

Sex ratio

To find out the proportion of sexes, the offspring of twenty females of *B. alfierii* was recorded. This was accomplished by isolating pairs, of one male and one female each, in small Petri dishes 3 cm. in diameter containing sufficient quantities of conditioned berseem seeds on which the females lay their eggs. The object of using the Petri dishes was to avoid as much as possible the deposition of more than one egg on one seed. Two series of experiments were carried out at 32°C. and 50% R.H., using in each series

twenty pairs. In the first series the adults used were taken from a stock kept at 32°C. and 50% R.H. for about three generations after the adults had been collected from the field. The offspring in this case consisted of both *B. alfieri* and *B. trifolii*. The resulting males of both forms together were 192 and the females were 223, thus 46.3% were males and 53.7% were females.

In the second series, the adults used were taken from a stock kept at 32°C. and 50% R.H. for a period of about two years. The offspring in this case consisted wholly of *B. alfieri*, of which 327 were males and 332 were females, with the percentage of 49.6% and 50.4% for males and females, respectively. In this experiment out of the 659 resulting adults, only one was of the *trifolii* form.

It is evident, therefore, that the number of females slightly exceeds that of the males, and the deviation from a 1:1 sex ratio is usually small. It should be noted that this was not the case with the offspring of the separate pairs, in some cases the number of adults of one sex exceeded that of the other sex while in other cases the number of both sexes was equal.

Sexual maturity

Adults of *Bruchidius alfieri* emerge from the seeds in a fully mature condition, the abdomen of the female is greatly distended with the mature ova inside. Copulation takes place soon after emergence and the eggs are laid within few hours.

Adults of *B. trifolii* emerging from the seeds during the breeding experiments in the laboratory never reached sexual maturity, no mating was observed throughout life and the female died without oviposition. This was confirmed by dissecting the genital system of females at different intervals during their life period.

In the field, it seems that sexual maturity of *B. trifolii* begins in March. The ovaries of several females were dissected during that month and it was found that the egg follicles began to appear, and by the end of the month ripe eggs were seen inside the ovaries. Abo- R a y a (1954) found also that insects swept before the last days of March died without oviposition, whereas those swept later laid eggs.

These observations are in accordance with the findings of Skaife (1926), that copulation takes place soon after emergence in the case of those species that breed more or less continuously throughout the year, but those species that have only one generation a year do not copulate until the host plants are beginning to set seeds.

6. Mating

Copulation was not observed in *Bruchidius trifolii*, whereas adults of *B. alfieri* taken just after emergence were found to start mating as soon as males

and females were brought together. The male is aggressive and insistant and continues to follow the female about very closely, striking her with his antennae. During coitus, the female remains stationery and exhibits no excitement. It does not change its normal position whereas the male stands on its hind legs catching the female by its fore and middle legs and introducing its penis into the female genital opening. No part of the female genitalia is seen. So, during copulation, the long axis of the body of the male is more or less perpendicular to that of the female. One hundred and twenty pairs taken from a stock kept at 32°C. and 50% R.H. were observed while copulating and the duration was recorded in each case. It has been found that copulation lasts from 2.5 to 12.5 minutes with an average of 5.5 minutes. When coitus is over, the female and not the male makes the initial attempt for release; the male appearing helpless to extricate himself. The separation of the bodies of the two sexes one from the other is accomplished by the female pushing against the male with her hind legs, the male during this time remaining quiet. Sometimes, however, the female moves about for sometime, dragging the male behind her while he is still introducing his penis into her until separation takes place. The author observed males in copula with dead females. A similar observation was reported by Larson and Fisher (1938) from *Callosobruchus maculatus* (F.).

Copulation under normal conditions takes place more than once during life.

Parthenogenetic reproduction does not occur, and the unmated females deposit a considerable number of eggs which soon shrivel and collapse.

7. Habits of the adult

The adults move very actively at high temperatures (e.g. 32°C.), while at low temperatures (e.g. 16°C.) they are very inactive and extremely sluggish in movement. In *Bruchidius trifolii*, the males and females are swift fliers as they posses well developed hind wings. This is also the case in the male of *B. alferii*, but not in the female owing to the relatively samll size of its hind wing.

The adults, when molested, may take to the wing, or fold their legs and antennae against the body and feign death, a phenomenon which is common among Coleoptera.

Concerning the feeding habits of the adults, it is assumed that they, under normal warehouse conditions, take neither food nor drink. The adults carry with them from the larval stage over the pupal stage a stored amount of energy in the form of fat body and as soon as this energy is exhausted, the adult dies. On the contrary, in the field, adults of *B. trifolii* are seen often visiting the flowers of berseem and sometimes the awns of wheat, probably feeding on the nectar. It may be noted that food is not essential

for the reproduction of *B. alfieri*, but is probably important for *B. trifolii* to reach sexual maturity.

The effect of food on the various life processes of the adults of *B. alfieri* will be discussed later.

8. Longevity of the adult

All the following experiments on longevity, oviposition, fecundity, etc., were carried out on *Bruchidius alfieri*, since this is the form which could be bred in the laboratory.

Effect of temperature and humidity

To study the effect of temperature and humidity on the longevity of the adult, newly emerged beetles were taken from a stock kept at 32°C. and 50% R.H. within twelve hours after emergence. Each pair, one female and one male, was put in a glass tube 2 × 0.7" together with 50 conditioned berseem seeds. They were placed in desiccators containing KOH solutions giving the desired humidities. The different humidities used were 30, 50, 70 and 90% R.H.; 100% R.H. was not used owing to the rapid development of fungus on the seeds. The effect of these four relative humidities was tested at four different temperatures, namely 16, 23, 28, and 32°C. Records were taken of the length of life of both sexes, the results are shown in Table I.

Generally, the average longevity of the male is longer than that of the female as shown also in Figure 4. The difference between the longevitys of both sexes generally increases with decrease of temperature at all the relative humidities used. With respect to humidity, it is evident that the difference between the male and female in longevity increases with rise of the relative humidity at all the temperatures used except at 32 and 16°C. where the difference is slightly less at 90 than it is at 70% R.H.

At low temperature (16°C.), adults of both sexes lived much longer than at high temperature (32°C.), the longevity as a rule decreasing with rise of temperature at all the relative humidities. This may be due to the fact that at high temperatures, the energy stored up in the fat body of the adult is consumed more rapidly than at lower temperatures (Zacher, 1928), and as in other bruchids under normal warehouse conditions, the adults taking neither food nor drink, they die soon after the fat body is exhausted. For instance, at 32°C. and 50% R.H. the female lived for an average of 3.65 days. At 28°C. and the same relative humidity, the longevity of the female is about 1.4 times its value at 32°C.; at 23°C. it is nearly 2.5 times, and at 16°C. it reaches 5.9 times. Similarly, the longevity of the male at 32°C. and 50% R.H. is 8.72 days on the average. At 28°C. and at the same relative humidity the male lived 1.6 times longer than at 32°C., 2.3 times at 23°C., and 4.2 times at 16°C.

TABLE I

Effect of temperature and humidity on the longevity of the adult.

TEMPERATURE IN °C.	PERCENTAGE RELATIVE HUMIDITY	NUMBER OF OBSERVATIONS	LENGTH OF LIFE IN DAYS				DIFFERENCE BETWEEN AVERAGE LONGEVITIES OF BOTH SEXES IN DAYS
			FEMALE		MALE		
			RANGE	MEAN ± STANDARD ERROR	RANGE	MEAN ± STANDARD ERROR	
32	30	20	3-5	3.5±0.2	4-11	6.8±0.4	3.3
	50	20	3-5	3.7±0.2	6-17	8.7±0.7	5.0
	70	19	3-6	4.1±0.2	4-13	9.3±0.5	5.2
	90	20	3-7	4.3±0.3	6-16	9.0±0.5	4.7
28	30	20	5-7	5.7±0.2	9-19	13.3±0.5	7.6
	50	20	4-8	5.2±0.3	9-19	13.7±0.7	8.5
	70	20	3-9	5.7±0.3	6-30	15.9±1.2	10.2
	90	19	4-11	6.6±0.5	11-25	17.1±1.0	10.5
23	30	20	7-12	9.2±0.3	11-22	17.7±0.6	8.5
	50	19	6-12	9.1±0.4	14-31	20.3±1.2	11.2
	70	20	5-16	9.9±0.6	16-35	22.3±1.2	12.4
	90	20	5-14	9.1±0.6	18-34	24.0±1.2	14.9
16	30	15	15-31	19.8±1.1	15-49	31.0±2.6	11.2
	50	16	12-29	21.6±1.3	22-52	37.2±2.5	15.6
	70	15	16-32	18.6±1.8	30-54	40.9±2.0	22.3
	90	16	15-39	23.2±1.7	27-65	43.0±3.0	19.8

It is clear from Table I that at moderate and low temperatures (28, 23 and 16°C.) the longevity of the male increases with rise of relative humidity, while at high temperatures (32°C.) it increases as the relative humidity is increased up to 70% after which (i.e. at 90% R.H.) a slight decrease is observed. In case of the female, the longevity increases with increase of relative humidity at 32°C., whereas no regularity could be traced at the three other temperatures (28, 23 and 16°C.).

Differences in the longevity of the female due to change in the relative humidity at a constant temperature are not significant statistically. In case of the male, the difference in longevity is only significant at 32°C., and highly significant at 23°C. due to change in the relative humidity from 30 to 50%.

It is, therefore, clear that high humidities (70 and 90%) are more favourable for the adult life than low ones (30 and 50%) at all the temperatures used.

A series of experiments was carried out in August at natural summer conditions (28-31°C. and 38-61% R.H.). Twenty pairs each of one male and one female taken from a stock kept at 32°C. and 50% R.H., were placed in 2×0.7" specimen tubes together with 50 berseem seeds. The female lived for 3-5 days with an average of 3.8 ± 0.1 , and the male for 7-15 days with an average of 10.6 ± 0.6 .

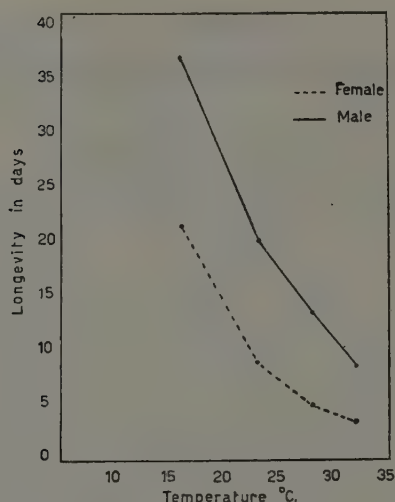


Fig. 4 : Longevity of adult *B. alfieri* at different temperatures (constant R.H. 50%).

Effect of mating on longevity

The effect of mating on the longevity of *B. alfieri* was tested by isolating unmated males and unmated females and comparing their longevity with mated individuals.

Unmated beetles were obtained from seeds (kept at 32°C. and 50% R.H.) containing full grown adults about to emerge. These seeds were placed singly in 2×0.7" specimen tubes and kept under continuous observation. Beetles emerging were transferred each to a specimen tube containing 50 conditioned berseem seeds and the length of life of each was recorded. The experiments were carried out at 32°C. and 50% R.H.

Table II (a and b) and Figure 5, show the results of these experiments. Mating seems to have a marked influence on the longevity of both sexes, unmated beetles living longer than mated ones.

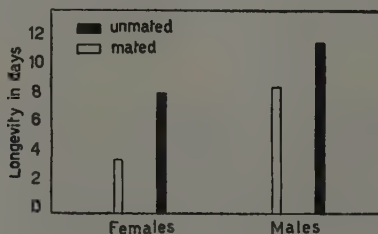


Fig. 5 : Longevity of mated and unmated individuals of *B. alfieri* at 32°C. and 50% R.H.

TABLE II

Effect of mating, repeated copulation and delayed fertilization on the longevity of the adult (32°C. and 50% R.H.)

STATUS	NUMBER OF OBSERVATIONS	LENGTH OF LIFE IN DAYS			
		FEMALE		MALE	
		RANGE	MEAN ± STANDARD ERROR	RANGE	MEAN ± STANDARD ERROR
(a) Mated*	20	3-5	3.7±0.2	6-17	8.7±0.7
(b) Unmated	20	6-13	8.3±0.4	8-18	11.8±0.8
(c) Copulating once	20	4-8	5.2±0.3	6-18	11.5±0.8
(d) Copulation one day after emergence	20	4-6	4.7±0.1	6-15	9.2±0.5

*These mated adults are those which copulated several times (comparison with c) and just after emergence (comparison with d).

The influence of mating on the longevity is much more pronounced in case of the females. The longevity of unmated females is about 2.3 times that of mated ones, while unmated males lived 1.4 times longer than mated males.

Effect of repeated copulation on longevity

The effect of repeated copulation has been studied on the longevity of both sexes. For this purpose, newly emerged beetles were used, one male and one female were brought together and after copulation which took place immediately, they were separated each in a 2×0.7" specimen tube with 50 conditioned berseem seeds. Another experiment was carried out in which the male was left with the female throughout life; in this case, they were observed to copulate more than once. Both experiments were conducted at a constant temperature of 32°C. and 50% R.H., and the adults were taken from a stock kept under the same conditions. The results are included in Table II (a and c).

Individuals allowed to mate once only lived for a longer period than those given the opportunity to copulate more than once. Statistical analysis indicates that the increase in the longevity is significant in the males and highly significant in the females. The difference in the maximum longevity of the males due to repeated copulation is very slight as compared with that of the female.

By comparing the results shown in a, b and c of Table II, it is clear that the maximum longevity is attained by unmated individuals, those allowed to copulate once only lived for a shorter period, while those which copulated

several times had the shortest longevity. The energy lost up in copulation most probably affects the longevity and causes a decrease in the length of the adult life. It may also be pointed out that the difference between the longevity of unmated individuals and those copulating once is very slight in males (0.3 day), and much more pronounced in females (3.1 days).

Effect of delayed fertilization on longevity

To investigate the effect of delayed fertilization on the longevity of the adult, newly emerged unmated beetles were separated singly in $2 \times 0.7''$ specimen tubes containing 50 conditioned berseem seeds. Twenty-four hours after emergence, every male and female were put together in a specimen tube with 50 conditioned seeds, thus mating was retarded one day. The longevity of both males and females was recorded and compared with others which were allowed to mate soon after emergence from the seeds. The experiments were conducted at a constant temperature of 32°C . and a constant relative humidity of 50%. The results are shown in Table II (a and d).

It was found that the beetles which mated one day after emergence lived for a longer period than those which mated immediately after emergence. This effect of delayed fertilization was clear in the females, and the difference was statistically significant.

Effect of food on longevity

The effect of food on the different life processes of the adult has been demonstrated in a number of bruchid beetles, e.g. *Bruchus quadrimaculatus* Fab. (Larson and Fisher, 1924), *Acanthoscelides obsoletus* Say (Larson and Fisher, 1938; Zaazou, 1948), and *Callosobruchus maculatus* F. (Larson and Fisher, 1938). It was shown in these insects that the average length of life of the adults is prolonged by access to water, sugar solution or honey as compared with those receiving no food.

In order to determine whether or not the presence of these foods would aid the adults of *Bruchidius alferii* to live longer than they ordinarily do under normal warehouse conditions, four series of experiments were conducted. Every series consisted of 20 pairs of newly emerged beetles, each pair placed in a $2 \times 0.7''$ specimen tube containing 50 conditioned berseem seeds. To the first series a drop of water was added, to the second a drop of sugar solution, to the third a drop of honey, the fourth which contained seeds only was used as control. All these were kept at 32°C . and 50% R.H. Because of the evaporation of water, it had to be replenished daily, honey and sugar less frequently. Daily observations were made, and the dates of death of beetles were recorded. The results summarized in Figure 6 show that food increases the length of life of the adult, maximum longevity being attained in beetles receiving honey, while those left without food showed the lowest longevity.

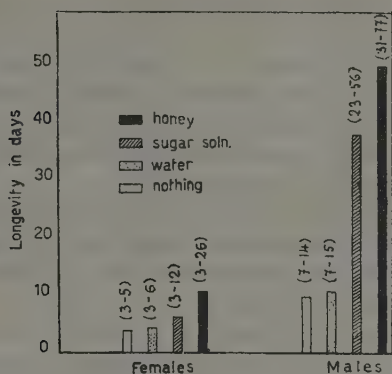


Fig. 6: Longevity of males and females of *B. alferii* given different foods at 32°C. and 50% R.H.

The difference between the average longevity of beetles given water and that of beetles used as control is rather slight in both sexes, though highly significant statistically in the females. This is not attributed to an increase in the air humidity brought about by the water inside the tubes, because Z a a z o u (1948), working on *Acanthoscelides obsoletus* Say, found that there was no striking difference in the average longevity when a moistened piece of blotting paper was put in the tubes for one hour only every day instead of putting a drop of water on the sides of the tubes. This indicates that it is the actual drinking of water which caused this slight increase in longevity.

There is a striking difference between the longevity of beetles given honey or sugar solution and that of beetles given water or nothing. The female longevity was nearly 1.6 times longer in the sugar solution-fed beetles and about three times longer in the honey-fed group as compared with non-fed ones. In case of males given sugar solution and honey, the longevity was about 4 and 5 times as those receiving nothing respectively.

Beetles fed on honey had maximum longevity of 77 and 26 days for males and females, respectively. Those feeding on sugar solution showed maximum longevity of 56 and 12 days for males and females, respectively. The maximum length of life in the water-fed group and in the non-fed one are very close to each other, being 15 and 14 days for the males and 6 and 5 days for the females.

9. Oviposition

Pre-oviposition period

Adults taken immediately after emergence from the seeds were found to start copulation as soon as males and females were brought together. Egg-

laying began within very few hours at 32°C., so that in 3 to 4 hours after copulation, eggs were found adhered to the seeds. At 28 and 23° C., the pre-oviposition period was little longer, but always less than one day. At 16° C. the period usually lasted about two days, sometimes reaching a maximum of nine days. In very few experiments, however (4 out of 60), one or two eggs were laid less than 24 hours after emergence. Humidity on the other hand seems to have no effect on that period.

Bushnell and Boughton (1940), in comparing the egg-laying in mated and unmated individuals of *Acanthoscelides obtectus*, found that in the latter case oviposition was markedly delayed. They came to the conclusion that mating has a pronounced effect on the stimulus to early laying. Mukerji and Bhyua (1937), working on *Bruchus quadrimaculatus*, found that unmated sexually mature females do not lay eggs and hence they concluded that mating in one way or the other induces relaxation of the musculature controlling the egg passages. The results obtained from experiments on *Bruchidius alferii* are in agreement with those of Bushnell and Boughton (1940). The egg-laying of unmated females is delayed for an average of one to three days.

Oviposition sites

The eggs of *Bruchidius alferii* are laid singly on the surface of the seed coat to which they are firmly glued by means of a gummy substance that is secreted prior to oviposition (Fig. 7). This is the case in the majority of the Bruchidae. In some instances, as in *Acanthoscelides obtectus* (Skafte 1926, Larson and Fisher 1938, Back 1940, and others), the eggs are not cemented to the seed coat, but are dropped loosely among the seeds.

Usually, one egg is attached to a single seed, but sometimes two or three eggs are deposited on the same seed. As many as eight eggs may be counted, in badly infested material, on a single berseem seed measuring about 2 mm. in length.

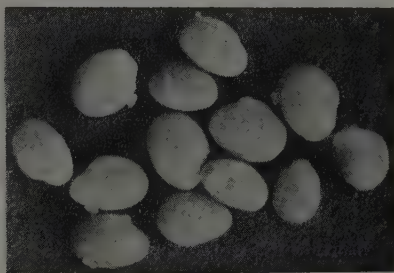


Fig. 7 : Berseem seeds showing eggs adhered to them.

Normally, the egg is cemented to the surface of one seed; sometimes it is attached to two adjacent seeds or laid between a seed and the wall of the specimen tube containing the seeds.

In order to determine whether the female prefers sound seeds to injured ones for egg laying, a Petri dish 5 cm. in diameter was divided by cardboard stripes into 12 compartments which were filled alternatively with sound seeds and seeds possessing the exit hole of the adult. Adults were sprayed over the seeds to lay eggs on. It was found that there is a marked preference to sound seeds as nearly all the eggs were laid on them, while very few eggs were deposited on the injured ones.

Stimulus to oviposition

In order to find out whether the presence or absence of seeds affects the number of eggs laid by the female, ten pairs of newly emerged beetles were placed separately in 2×0.7" specimen tubes without seeds, and kept at 32°C. and 50% R.H. In one tube the female died without laying any eggs, in another 8 eggs were laid by the female, and in the remaining eight tubes the number of eggs varied from 23 to 41. The eggs were attached by means of the glutinous secretion to the glass walls of the containers. Another series of experiments was carried out under the same conditions of temperature and humidity, but the adults were provided with seeds. In this case, the number of eggs laid varied from 27 to 66, with an average of 49. This indicates that the absence of seeds caused a marked reduction in the number of eggs laid by the female, and hence the presence of seeds seems to act as a stimulus to oviposition. According to Zacher (1929), smell plays a part in oviposition, and the sense of touch acts also as an inducement. This author arrived at this last conclusion (concerning the sense of touch) after observing that no eggs were laid by females of *Spermophagus subfasciatus* on seeds with peeled off skins. Larson and Fisher (1938) stated that insects are guided to the seeds mainly by smell, and that sight is of minor importance. Vukasoitch (1949) came to the conclusion that the females are attracted to the seeds by a sort of chemotactic reaction.

10. Fecundity

The procedure followed in studying the possible effect of the different factors on the number of eggs laid per female is the same as that described for the study of the longevity. Adults were taken from a stock kept at 32°C. and 50% R.H., and all the experiments, except those dealing with the effect of temperature and humidity, were conducted at the same conditions of the stock. Eggs were removed and counted daily.

Effect of temperature and humidity on fecundity

As shown in Table III, the total number of eggs laid per female is not greatly affected by variations in temperature from 32 to 23°C. At 16°C., a great reduction in the total number of eggs laid was noticed, the female laying about half the number of eggs deposited at the other temperatures

TABLE III
Effect of temperature and humidity on the total output of eggs

TEMPERATURE IN °C.	PERCENTAGE RELATIVE HUMIDITY	NUMBER OF OBSER- VATIONS	TOTAL NUMBER OF EGGS LAID PER FEMALE	
			RANGE	MEAN ± STANDARD ERROR
32	30	20	27-76	47.7 ± 1.8
	50	20	39-80	52.2 ± 2.1
	70	20	30-64	46.8 ± 2.0
	90	20	21-72	45.9 ± 3.2
28	30	20	24-67	46.5 ± 2.4
	50	19	35-66	47.6 ± 2.2
	70	19	22-64	45.5 ± 2.5
	90	19	20-70	52.5 ± 2.9
23	30	19	23-60	46.7 ± 2.3
	50	18	23-56	45.6 ± 2.3
	70	20	25-74	52.9 ± 2.8
	90	20	23-70	48.9 ± 2.6
16	30	15	8-47	22.0 ± 3.2
	50	16	9-41	24.4 ± 2.7
	70	15	7-41	24.1 ± 2.5
	90	16	15-49	28.2 ± 2.2

for all the relative humidities used. All the eggs laid at this low temperature failed to hatch and collapsed sometime after deposition.

The relative humidity, on the other hand, seems to have no significant effect on fecundity; no regularity could be traced as to increase or decrease in the number of eggs laid as the relative humidity was raised. The differences due to change in the relative humidity are statistically insignificant, except at 23°C. where the increase in the number of eggs as the relative humidity was raised from 50 to 70% was slightly significant.

The maximum number of eggs laid by a single female at all the different conditions of temperature and humidity was 80, this was observed at 32°C. and 50% R.H.

A series of experiments was conducted in August at natural summer conditions (28-31°C. and 38-61% R.H.). Twenty pairs of beetles, each of one male and one female taken from a stock kept at 32°C. and 50% R.H., were placed in 2 × 0.7" specimen tubes together with 50 berseem seeds to lay eggs on. Eggs were removed and counted daily. The total output of eggs per female ranged between 26 and 69, with an average of 45.9 ± 2.1.

Effect of mating

Eggs laid by mated females significantly outnumber (about one and a half times) those laid by unmated ones. The average number of eggs laid daily per female is 52.2 ± 2.1 (range 39-80) for mated ones as compared with 33.1 ± 1.9 (range 22-51) for unmated ones. Similar observations were reported by Bushnell and Boughton (1940) in *Acanthoscelides obtectus* Say. Unfertilized eggs soon collapse after deposition.

Effect of repeated copulation

Copulation takes place more than once throughout life. Repeated copulation tends to increase the total output of eggs per female. The average number of eggs laid by a female copulated once was 45.0 ± 2.7 (range 22-64), that of repeatedly copulated females was 52.2 ± 2.1 (range 39-80).

Effect of delayed fertilization

Adults kept without fertilization for one day after emergence laid no eggs on that day since the preoviposition period for non-fertilized females is not less than one day. The number of eggs produced by females whose fertilization was delayed is distinctly lower (44.1 ± 1.9 on the average ranging from 25-62) than that (52.2 ± 2.1 on the average ranging from 39-80) produced by females fertilized immediately after emergence.

Effect of food

An examination of Table IV shows that the average total output of eggs per female varied with respect to differences in food, increasing from beetles receiving nothing to those receiving water, then to those given sugar solution, and lastly to those fed on honey. The increase in the total output of eggs due to the drinking of water or feeding on sugar solution was statistically significant, whereas in the honey-fed group the increase was highly

TABLE IV
Effect of food on the total output of eggs (32°C. and 50% R.H.)

FOOD	NUMBER OF OBSERVATIONS	TOTAL NUMBER OF EGGS LAID PER FEMALE	
		RANGE	MEAN \pm STANDARD ERROR
Honey	20	38-108	64.4 ± 3.9
Sugar solution	20	32-80	54.6 ± 3.0
Water	20	36-77	50.4 ± 2.2
Nothing (control)	19	27-66	49.3 ± 2.5

significant. The maximum number of eggs produced by a single female during the whole of its life was found to be 108. This distinctly high number was recorded from a female given honey.

That food or drink causes an increase in the number of eggs laid by the female has been previously demonstrated in *Bruchus quadrimaculatus* (Larson and Fisher, 1924), *Spermophagus subfasciatus* (Zacher, 1929), *Acanthoscelides obtectus* (Larson and Fisher, 1938; Zaazou, 1948), and *Callosobruchus maculatus* (Larson and Fisher, 1938).

11. Rate of oviposition

Effect of temperature and humidity

Short lived insects generally lay most of their eggs during the first days of their life, the number of eggs decreasing towards the life end. For the determination of the oviposition rate, the average daily output of eggs per female was calculated. This was accomplished by placing twenty pairs of one male and one female each (taken from a stock kept at 32°C. and 50% R.H.), singly in 2 × 0.7" specimen tubes containing 50 conditioned berseem seeds; the seeds were changed daily and the eggs of each pair were counted. The

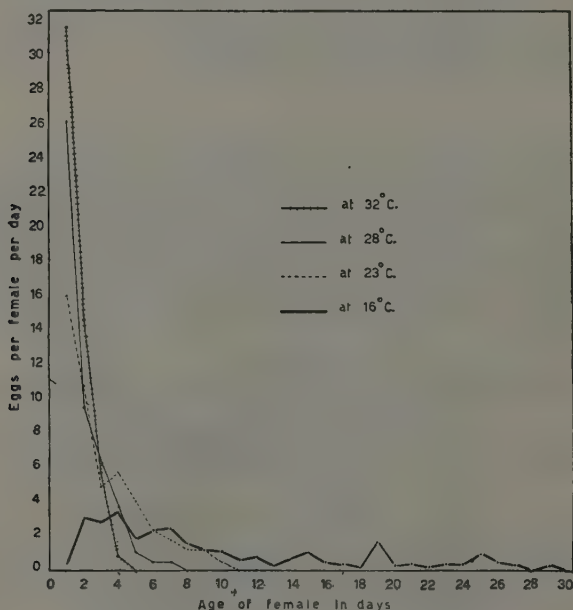


Fig. 8 : Rate of oviposition of *B. alferii* on berseem seeds at different temperatures with the relative humidity constant at 50%.

total number of eggs laid daily by all the females was divided by the number of females still surviving on the day of observation. This experiment was conducted at four different temperatures namely 32, 28, 23 and 16°C., using 30, 50, 70 and 90% R.H. It has been found that changes in the relative humidity seem not to affect the rate of oviposition. The results of the average number of eggs laid daily by the female at the four temperatures using 50% R.H. are represented graphically in Figure 8.

It is clear from Figure 8 that at high (32°C.) and moderate (28 and 23°C.) temperatures, the greatest number of eggs is laid on the first 24 hours, then the number decreases gradually as the female advances in age. For instance, at 32°C. the female lays during the first day of its existence about half the total number of eggs laid throughout its life. At 16°C., there is no distinct regularity in the oviposition rate. At this temperature the oviposition period is greatly prolonged, and there are occasionally intervals of some days (which may reach ten days) during which no eggs are laid.

Effect of mating on oviposition rate

In order to study the effect of mating on the rate of egg laying, twenty virgin females (taken from a stock kept at 32°C. and 50% R.H.) were kept separate in 2×0.7" specimen tubes in which 50 conditioned seeds were placed, the seeds being changed daily and the eggs laid by each female being counted. Twenty other tubes contained separate pairs of one male and one female each (taken from the same stock), and the number of eggs laid was

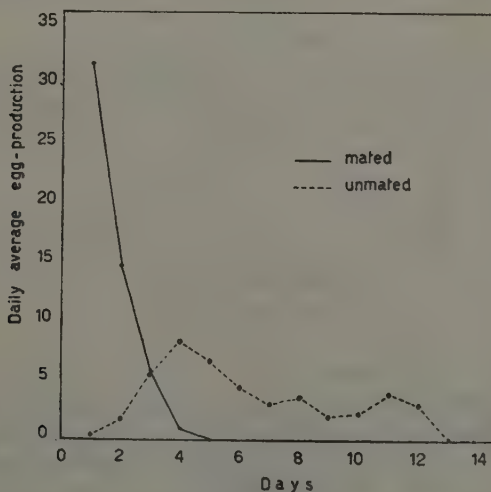


Fig. 9 : Rate of oviposition of mated and unmated females of *B. alferii* at 32°C. and 50% R.H.

similarly recorded. The two series of experiments were conducted at 32°C. and 50% R.H. The average daily output of eggs per female was taken by dividing the total number of eggs laid daily by all the females of the same series on the number of females still surviving on the day of observation. The results are represented graphically in Figure 9. A very marked difference in the rate of egg laying exists between the mated and unmated females. It is obvious that in mated females the number of eggs laid is very high at first and then decreases gradually. On the other hand, unmated females lay very few eggs at first, then the number increases gradually to reach its peak on the fourth day, tapering off gradually afterwards. At their peaks,

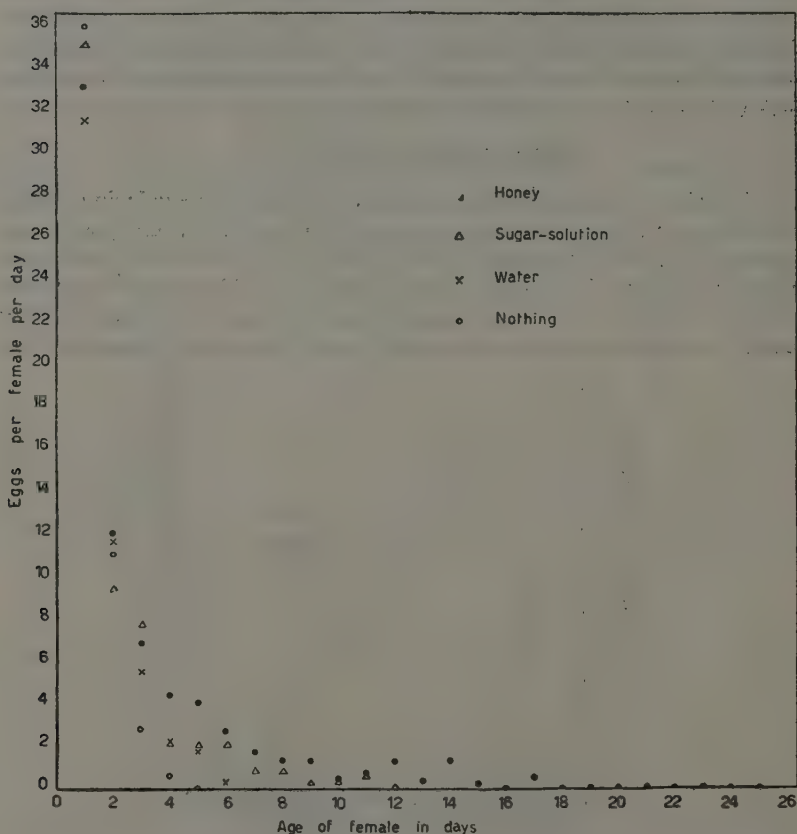


Fig. 10: Rate of oviposition of females of *B. alferii* when given different foods at 32°C. and 50% R.H.

the mated females laid an average of 31.9 eggs, whereas unmated females laid an average of 8.3 eggs.

Effect of food on oviposition rate

In this case four series of experiments were conducted; in each series twenty $2 \times 0.7''$ specimen tubes were used. Each tube contained a pair (one male and one female) of newly emerged beetles together with 50 conditioned berseem seeds. The adults were given a drop of honey in the first series, a drop of sugar solution in the second, a drop of water in the third, and in the fourth series they were given no food and used as control. Adults taken were from a stock kept at 32°C . and 50% R.H. These are the same conditions used for all the experiments. The seeds were changed daily and the eggs laid by each female were counted.

The daily average number of eggs laid by all the females in a series was taken by dividing the total number of eggs laid every day on the number of females which were alive on that day. The results are shown in Figure 10.

The graph indicates that food did not give significant differences in the maximum number of eggs laid by females under experimentation. It shows that the oviposition rate was a maximum on the first day and dropped suddenly on the second day, and gradually till the end of the female's life. But it can be noticed, however, that food has some effect on the lengthening of the adult life and also its productivity because, as the graph shows, these are much longer in the case of adults given honey or sugar solution than in those which are given water or no food.

12. Egg stage

The egg (Fig. 11) is elongate, oval in shape with rounded ends, one end broader than the other one. The broader end corresponds to the anterior end

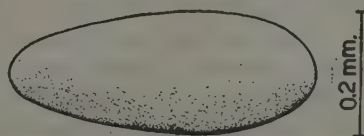


Fig. 11 : Egg of *B. alferii*.

of the future larva. The surface of the egg is smooth, with no visible sculpture. The average length of the egg is 0.48 mm., with a maximum of 0.55 mm. and a minimum of 0.45 mm. The width of the egg ranges between 0.17 mm. and 0.21 mm., with an average of 0.20 mm.

When first laid, the egg is glistening and pale yellow in colour. It darkens slightly during post-embryonic development. One to two days prior

to hatching at 32 and 28°C. and 2-4 days at 23°C., the young larva becomes retracted in the posterior half of the egg whereby its black head can be seen plainly through the transparent egg shell.

Unfertilized eggs are exactly similar to fertilized ones in shape and dimensions.

Incubation period

The data on the effect of temperature and humidity on the incubation period of the eggs are summarized in Table V. The duration of the egg stage depends greatly on temperature. It is shorter at high temperature (32°C.), and increases with the decrease of temperature. At 16°C., the eggs failed to develop, they collapsed some days after having been laid.

The incubation period seems to undergo slight changes at different relative humidities. Statistical analysis reveals that these changes are highly significant, except at 23°C. where the effect due to change in the relative humidity from 50 to 70% or from 70 to 90% is insignificant.

About 60 eggs were left to hatch under natural summer conditions (28-31°C. and 38-59% R.H.), during August. They hatched in 5-6 days with an average of 5.34 ± 0.07 .

The eggs in the above experiments were not taken from the stock kept at 32°C. and 50% R.H., but the data were obtained from eggs laid at the temperatures and humidities in which they hatched. This is because the eggs are glued to the seeds which have to be conditioned for about three weeks before use.

13. Larval and pupal stages

On hatching, the first stage larva bores directly into the seed from the egg. It bites a neat round hole in the chorion on the underside of the broad end of the egg, where it is in contact with the substratum. In the process of boring into the seed, the material excavated by the larva comes in the form of a fine white powder or meal. This is worked back along the grooves found on the inner sides of the mandibles and fills a large part of the egg shell, giving it a white appearance. Mukerji (1938) assumed that this substance is an excretory product of the developing larva. Larvae which fail to penetrate directly from the eggs into the seeds move about freely and very few of these can get finally into the seeds, others cannot and die.

The first stage larva is provided with six thoracic legs and a chitinous plate on the prothorax which will be described later. This prothoracic plate was believed to play an important role in the act of penetration.

The larva feeds on and consumes all the contents of the seed, moults four times, and then pupates. One berseem seed contains sufficient nourishment to bring a single bruchid to maturity and so, if more than one larva

enter a seed, all of them feed and grow to a certain extent, but sooner or later, all except one of them die. The same condition was observed in *Bruchus pisorum* by Sk a i f e (1919 and 1926). This author, in an attempt to explain the cause of this phenomenon, stated that : "At first it was thought that the surviving grub was guilty of the murder of the others, that it ate its way through the seed until it came upon its rivals and killed them, each in turn, with its mandibles. Although this may sometimes happen, it is by no means invariably the case. Larvae separated by the whole diameter of the pea die and leave the field clear for the sole survivor. It seems as though they recognize, by some mysterious means or other, the presence of one another in the seed, and all except one unaccountably favoured individual stop feeding and die".

Duration of the larval and pupal stages

As already noted, the larval and pupal stages are spent inside the seed rendering it impossible to test the possible effect of temperature and humidity on the two stages separately. The effect of four relative humidities, viz. 30, 50, 70 and 90% R.H., was tested at three different temperatures, namely 32, 28 and 23°C. It was practically impossible to take the larvae from a stock kept at constant conditions owing to the fact that the first larval instar bores directly into the seed from the egg shell immediately after hatching and the seeds had to be conditioned three weeks before carrying out the experiments. So, the data were obtained from larvae developing at temperatures and humidities in which the eggs hatched. The date of emergence of each adult and its sex were recorded.

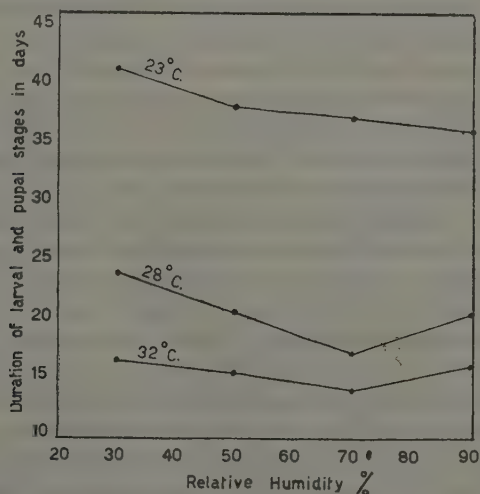


Fig. 12 : Duration of the larval and pupal stages under different conditions of temperature and humidity.

TABLE V

Effect of temperature and humidity on the duration of the developmental stages

TEMPERATURE IN °C.	PERCENTAGE RELATIVE HUMIDITY	INCUBATION PERIOD IN DAYS			DURATION OF THE LARVAL AND PUPAL STAGES IN DAYS		
		NUMBER OF OBSER- VATIONS	RANGE	MEAN ± STANDARD ERROR	NUMBER OF OBSER- VATIONS	RANGE	MEAN ± STANDARD ERROR
32	30	52	5	5.00±0.00	40	15-21	16.65±0.22
	50	57	5-6	5.10±0.04	52	14-20	15.51±0.14
	70	50	5-6	5.27±0.04	59	13-15	14.12±0.07
	90	51	4-6	4.97±0.04	35	14-22	16.22±0.47
28	30	143	8-9	8.20±0.03	95	19-36	23.18±0.27
	50	173	7-9	7.88±0.04	133	17-28	20.78±0.15
	70	179	7-8	7.26±0.03	132	15-27	17.26±0.13
	90	138	7-8	7.06±0.02	35	16-28	20.71±0.62
23	30	166	12-15	12.59±0.09	37	38-47	41.63±0.57
	50	64	12-14	12.28±0.07	46	34-53	38.28±0.57
	70	67	11-14	12.14±0.06	45	33-53	37.30±0.56
	90	134	11-14	12.2±0.05	24	32-47	36.27±0.71

It has been found that there is no difference in the duration of the larval and pupal stages with respect to the future sex.

Table V and Figure 12 show that temperature seems to have a marked influence on the duration of the larval and pupal stages. It is clear that at all the humidities used it is much longer at 23°C. than it is at 28 or 32°C., the difference being distinctly greater as the temperature is lowered from 28 to 23°C. than it is from 32 to 28°C.

Changes in the relative humidity also affect the larval and pupal duration. At 32 and 28°C., it decreases as the relative humidity is raised from 30 to 70%, then an increase takes place at 90% R.H. On the other hand, at 23°C., the larval and pupal duration decreases with increase of relative humidity from 30 to 90% R.H. The prolongation of the larval and pupal periods at 90% R.H. and 32 or 28°C. is probably due to the development of fungi on the seeds. This greatly suppresses the percentage of adults emerging, causing high mortality inside the seeds. The effect due to changes in the relative humidity is highly significant statistically at all the temperatures used except at 23°C. where it is insignificant as the relative humidity changes from 50 to 70% and from 70 to 90%. According to Menusan (1934), the factor controlled is the humidity outside the seeds, the relative humidity inside the seeds being probably higher due to the metabolic water given off by the larvae and pupae. A similar assumption was also stated by Schoof (1941).

Owing to lack of equipment, it has not been possible to test the effect of lower temperatures, e.g. 16°C., on the duration of the larval and pupal stages. Only it has been observed that the larva hatching at 32°C. and then transferred to 16°C. could withstand this low temperature although it was fatal to the eggs.

Number of larval instars

As in the greatest majority of the Bruchidae, there exists hypermetamorphosis in the development of *Bruchidius trifolii* and *Bruchidius alferii*, as the first stage larva differs in certain morphological peculiarities from the following stages. The first larval instar is distinguished mainly by the possession of legs and a chitinous plate on the pronotum. Such structures are specific for the first instar only and disappear after the first moult. Some authors differentiated between these two larval forms only and considered them as stages, e.g. Razzauti (1917), Daviault (1928), Hoffmann (1945), etc. But, according to several others, four larval instars were reported from a number of bruchid beetles, e.g. *Acanthoscelides obtectus* (Marcucci 1920, Larson and Fisher 1938), *Zabrotes subfasciatus* (Zacher 1930, and Steffan 1945), *Bruchus pisorum* (Brindley, 1933), *Callosobruchus maculatus* (Larson and Fisher, 1938), and *Bruchus obtectus* (Herford, 1935). Korab (1927), as stated by Larson, Brindley and Hinman (1938), lists five larval stages of the pea weevil according to measurements of the length and width of the insect at short intervals. These three latter authors added that the fifth evidently constitutes the prepupal stage.

Mukerji (1938), mentioned that moulting takes place more than twice in *Bruchus quadrimaculatus*, but he merely divided the larval life into two phases, the boring phase (corresponding to the first stage) and the nutritive phase (corresponding to the remaining larval stages).

The number of larval stages in *Bruchidius trifolii* and *B. alferii* is four as determined from breedings at 32°C. and 50% R.H. This was accomplished by finding out the differences in the width of the head capsule and in the mouth parts. The study of this insect, developing as it does within the seed, presents difficulties that make it impossible to conduct a series of measurements on an individual larva during its period of growth to determine the number of moults. So, a large number of seeds having eggs attached to their seed coats were kept under continuous observation. After hatching, 40 seeds were taken daily and soaked in water till the seed coat became soft enough. The seeds were then split and the larvae were removed from inside the seeds. The width of the head capsule was measured and preparations of the mouth parts were also made. This work continued till the emergence of the first adult, i.e. over a period of twelve days. The measurements of the head width of all the larvae are represented graphically in Figure 13. It is clear that there are four peaks indicating four larval instars. The range and mean head width of these instars are shown in Table VI. These four instars are accompanied by four moults. Zacher (1930) considered the first moult (on changing to the second stage) as growth and developmental moult

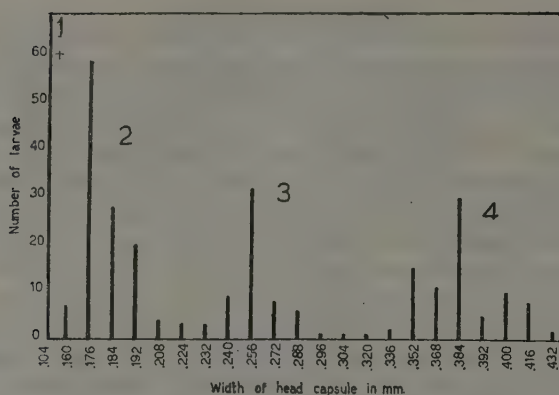


Fig. 13 : Number of larvae possessing different head widths.

TABLE VI

Measurements in mm. of the head-widths of the larval instars bred at 32°C. and 50% R.H.

LARVAL INSTAR	NUMBERS MEASURED	RANGE	MEAN
First	165	0.1040	0.1040
Second	121	0.1600-0.2240	0.1810
Third	61	0.2320-0.3200	0.2600
Fourth	83	0.3360-0.4320	0.3810

the second and third as pure growth moults, the fourth (on changing to pupa) as a pure developmental moult.

D y a r (1890) has shown that the width of the head-capsule of a lepidopterous larva is more or less constant for any instar of a given species and that the head width follows a regular geometric progression in successive instars. I m m s (1948) states that this law applies also to saw-fly larvae and Collembola. In *Bruchidius trifolii* and *Bruchidius alfieri*, D y a r's law could not be applied since different values were obtained by dividing the head width of each instar by the one which precedes it. This was also the case in *Zabrotes subfasciatus*, as stated by Z a c h e r (1930).

VI. MORPHOLOGY OF THE LARVAL INSTARS

1. First larval instar

The body of the first larval instar (Fig. 14) is very slightly arched. It is broad anteriorly and tapers gradually towards its posterior end. On hatching from the egg, it is very pale yellow in colour except the head and the

pronotum which are more or less dark brown. The average length of the larva is 0.47 mm. and the average breadth is 0.21 mm.

The first larval instar possesses certain characteristics which disappear after the first moult. These are the presence of the six thoracic legs, the prothoracic plate, the spines of the first abdominal segment, the macrochaetae and microchaetae which are disposed regularly on the body, and lastly the brown pigmentation of the head capsule.

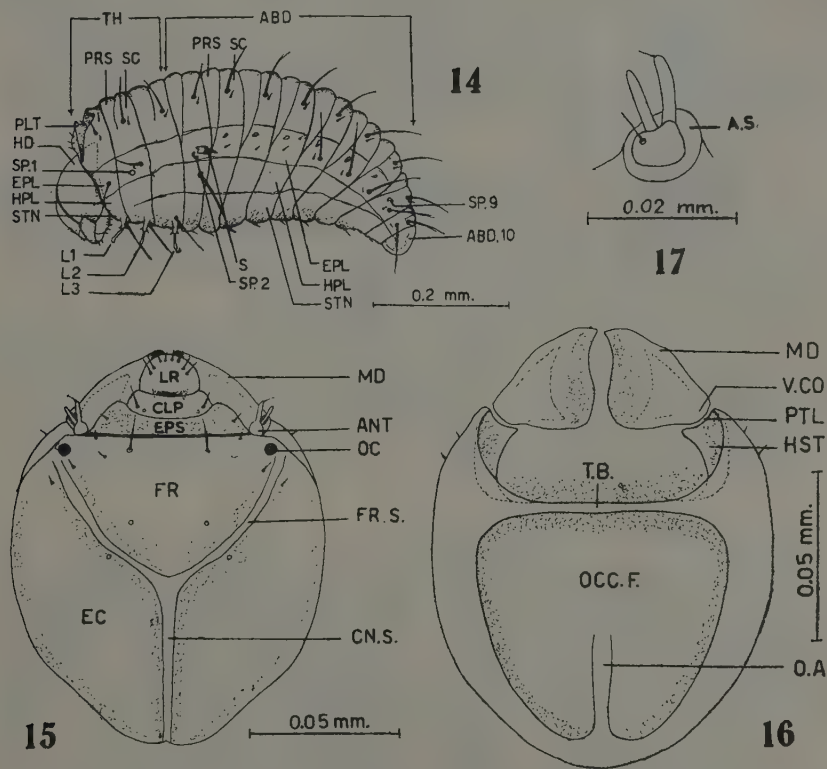


Fig. 14: First larval instar, lateral view (ABD, abdomen; ABD. 10, tenth abdominal segment; EPL, epipleuron; HD, head; HPL, hypopleuron; L1, L2, and L3, fore, middle and hind legs; PLT, prothoracic plate; PRS, prescutum; S, spine of the first abdominal segment; SC, scutellum; SP. 1, mesothoracic spiracles; SP. 2 and SP. 9, spiracles of the first and eighth abdominal segments; STN, sternum; TH, thorax). — Fig. 15: Head of the first larval instar, dorsal view (ANT, antenna; CLP, clypeus; CN.S., coronal suture; EC, epicranium; EPS, epistoma; FR, frons; FR.S., frontal suture; LR, labrum; MD, mandible; OC, ocellus). — Fig. 16: Head of the first larval instar, ventral view (HST, hypostoma; MD, mandible; O.A., occipital apodeme; OCC.F., occipital foramen; PTL, postcoila; T.B., tentorial bridge; V.CO., ventral condyle of the mandible). — Fig. 17: Antenna of the first larval instar (S.A., antennal socket).

Head

The head capsule (Figs. 15 and 16) is brown in colour. It possesses a well developed Y-shaped epicranial suture which appears as a white line in the middle of the dorsal side of the head. The coronal suture (Fig. 15, CN.S.) runs a straight course in the mid-dorsal line dividing the epicranium into two plates (EC), each bearing a short bristle together with a sensory pore. The frons (FR) is more or less triangular in shape and is bounded by the frontal sutures (FR.S.) laterally and posteriorly, and by the epistoma (EPS) anteriorly. It is provided anteriorly with four pairs of bristles and a pair of sensory pores. The epistoma (EPS) appears as a heavily chitinated sclerite at the anterior end of the frons, and is provided laterally with one bristle on each side. The clypeus bears two long bristles together with two sensory pores at their bases.

The occipital foramen (Fig. 16, OCC.F.) is limited anteriorly by the tentorial bridge (T.B.) which connects the posterior ends of the hypostoma (HST). This latter (HST) bears a facet (PTL) for the articulation of the ventral condyle of the mandible. An apodeme, the occipital apodeme (O.A.) projects into the occipital foramen at its posterior border.

The antenna (Fig. 17) consists of a broad basal segment carrying two long equal ones, one situated obliquely and directed towards the outer side, the others apical and ending by a long rigid spine pointing exteriorly. The basal segment of the antenna bears a long bristle.

At the base of each antenna there is a black spot which represents the simple eye or ocellus (Fig. 15, OC).

Mouth parts

The labrum (Figs. 15 and 18, LR) is semi-circular in shape, slightly chitinated except for a narrow rather more chitinated band posteriorly. It carries a row of four bristles at its distal margin, and two other longer pairs behind them. The epipharynx (Fig. 19) is membranous and carries two pairs of crochet-like spines. The epipharyngeal lamellae (LM) are in the form of two long chitinous rods slightly diverging anteriorly.

The mandibles (Figs. 20 and 21), apart from the variation in size, do not show any differences in the four larval instars. Each mandible is heavily chitinated and is more or less triangular in shape with a bluntly pointed apical tooth (Fig. 20, AP. T.). It articulates with the head through the lateral and ventral condyles. The lateral condyle (Figs. 20 and 21, L.CO.) fits against an emargination in the antero-lateral side of the head, while the ventral condyle (V.CO.) works against the postcoila (Fig. 16, PTL) on the hypostoma. The mandible, as in the larvae of other bruchid beetles, is characterised by the presence of a groove along its inner side (Fig. 21, GRV) which

probably serves to guide the excavated meal out into the egg shell during the act of boring into the seed. On the dorsal side of each mandible there are two long bristles and two sensory pores. Associated with each mandible are the tendons of the adductor and abductor muscles (Fig. 20, ADD and ABD), the former being considerably larger than the latter.

The maxilla (Fig. 22) consists of the cardo, the stipes, the palpifer, the maxillary palp, and the mala. The cardo (CD) is in the form of a well

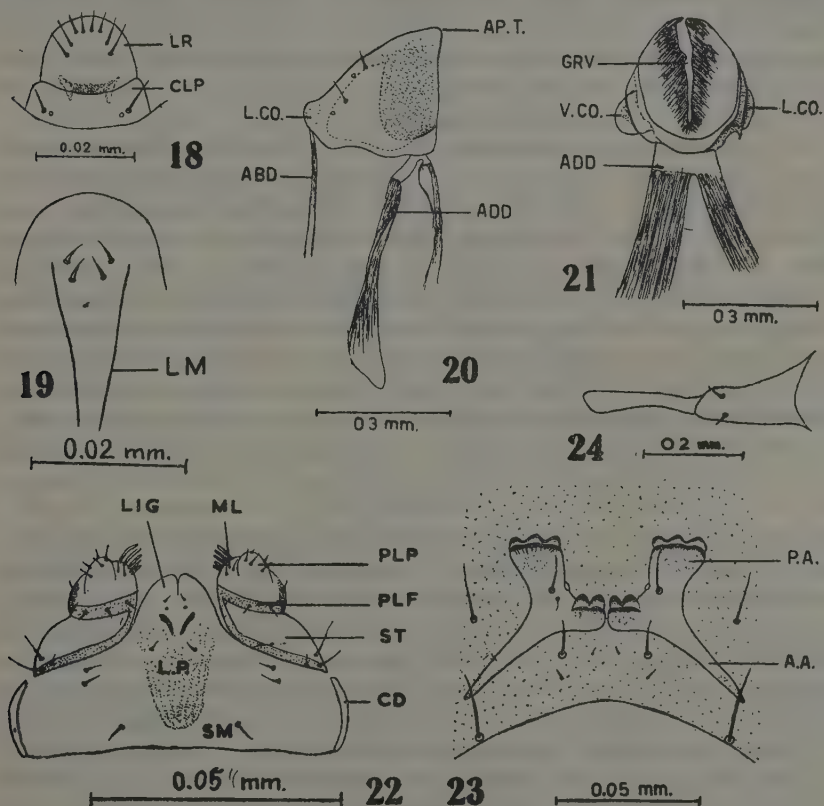


Fig. 18 : Labro-clypeus of the first larval instar (CLP, clypeus; LR, labrum). — Fig. 19 : Epipharynx of the first larval instar (LM, epipharyngeal lamella). — Fig. 20 : Left mandible of the first larval instar (ABD and ADD, tendons of the abductor and adductor muscles; AP.T., apical tooth; L.CO., lateral condyle). — Fig. 21 : Mandible of the first larval instar, inner view (GRV, groove along the inner side of the mandible; V.CO., ventral condyle; other lettering as in Fig. 20). — Fig. 22 : Subfacial region of the first larval instar, ventral view (CD, cardo; LIG, ligula; L.P., labial plate; ML, mala; PLF, palpifer; PLP, maxillary palp; SM, submentum; ST, stipes). — Fig. 23 : Prothoracic plate of the first larval instar (A.A., anterior arms; P.A., posterior arms). — Fig. 24 : Leg of the first larval instar.

chitinised elongate structure on the side of the submentum (SM). The stipes (ST) is more or less trapezoidal in shape with its basal part highly chitinised and brown in colour. This part carries ventrally a pair of bristles near its outer border. The distal non-chitinised portion of the stipes is larger than its basal part and bears ventrally a single bristle very close to those of the basal part. The palpifer (PLF) is very well chitinised and carries ventrally a row of five bristles. The galea and lacinia are fused together and form a single lobe, the mala (ML). This is provided with two bristles only on its ventral side. Distally, it is armed with a remarkable comb-like structure of five slightly curved flat spines of equal length arising from its dorsal side. The maxillary palp (PLP) is one-segmented and its surface is provided with two dorsal and three ventral bristles.

The elements of the subfacial region are not well defined from each other. Its posterior part is entirely membranous and is formed by the fusion of the submentum (Fig. 22, SM) and the articulating maxillary area (Boving, 1927). It is bounded on either side by the maxillary cardines (CD). Its ventral surface carries three pairs of bristles. The mentum and prementum are fused together and are not demarcated from the submentum. They show a median common escutcheon-like well chitinised sclerite known as the labial plate (L.P.). This latter carries a pair of short bristles. The ligula (LIG) is more or less triangular in shape and its distal end is slightly incised in the middle line. It is provided with a pair of short bristles and a pair of sensory pores at their bases. The labial palps are entirely lacking.

Thorax

The three thoracic segments (Fig. 14, TH) are all distinct. On the pronotum immediately behind the head, is found an H-shaped chitinous plate, the prothoracic plate of Kunhi Kanna (Nackenplatte of Zacher, 1930, and cephalic shield of Mukerji, 1938) (Fig. 14, PLT). Its anterior arms (Fig. 23, A.A.) are widely diverging from each other, much more than the posterior ones (P.A.). This prothoracic plate (Fig. 23) consists of two halves which are not joined together, but are brought very closely against each other in the mid-dorsal line, thus assuming the shape of an H. The posterior end of this plate is beset with a row of three chitinous blunt teeth on each half. In some cases four teeth were observed on each limb. At the level of the cross piece there are four teeth, two on each side, which are also blunt and similar to the posterior ones in shape and size. On each of the posterior arms of the plate there is a stiff bristle very near to the inner margin.

The prothoracic plate is characteristic of the Bruchid larvae. It varies considerably in size and number of teeth in the different members of the family. In some cases it is well developed and carries a larger number of teeth than those observed in the larvae of *Bruchidius trifolii* and *Bruchidius*

alfierii, especially on the posterior ends where there are 7 in *Mylabris quadrimaculatus*, 4 or 5 in *Mylabris obtectus*, etc. (Kunhi Kannan, 1923). In certain other instances, as *Zabrotes pectoralis*, the prothoracic plate is greatly reduced in size and is only represented by no more than four feeble teeth (Kunhi Kannan, 1923).

According to Kunhi Kannan (1919), the prothoracic plate stands on a small movable fold of skin, which can be rapidly moved backwards and forwards, so that the head may be nearly covered or completely free. This was not accepted by Mukerji (1938) who found after a study of the embryonic development of *Bruchus quadrimaculatus* that this plate being continuous with the cuticle arises as a separate sclerite. He added that "the shield is connected with the anterior and posterior limits of the head capsule by means of longitudinal as well as by transverse bands of muscles passing externally to the head capsule".

Concerning the function of the prothoracic plate in the bruchid larvae, there is diversity of opinion as to whether it takes part in the act of penetration into the seeds. As it is lost after the larva has penetrated into the interior of the seed, it is assumed to have an important bearing on the question of emergence of the larva. Riley (1892) observed this structure in the larva of *Bruchus fabae*, and mentioned that it is "of advantage in aiding the larva in the work it has to do", i.e. of boring into beans. Chittenden (1898) states that, in *Bruchus pisorum*, it assists the larva in obtaining entrance to the pea. Kunhi Kannan (1923), after an extensive study of the prothoracic plate in the larvae of several bruchid beetles, came to the conclusion that "the function of the prothoracic plate in Mylabrid larvae is to obtain purchase against the egg shell or other object against which the larva can lean, and to incline the head as required for excavating the hole". This latter author (1919 and 1923) carried out a series of experiments to prove that the larva, in the absence of contact with any surface dorsally, would fail to enter. He found that in species which lay their eggs firmly attached to the seeds, the prothoracic plate is brought at a convenient angle and fixed against the concave inner surface of the egg-shell when the larva begins boring. In other species, as *Mylabris obtectus*, which lays its eggs loosely among the seeds, the larva does not penetrate directly into the seed but wanders about for sometime and must have some surface as of an adjoining seed near the point of entry so that it may obtain a leverage against it. Skiff (1926), talking about this peculiar prothoracic plate, states that its use is not obvious but it would seem to be of assistance in enabling the larva to work its way along its burrow. Mukerji (1938) found that the prothoracic plate of the first larval instar of *Bruchus quadrimaculatus* is fixed against the flat surface of the egg which is in contact with the seed and not against the internal concave surface of the egg shell as reported by Kunhi Kannan (1919 and 1923). Lepesme

(1942), in criticising K u n h i K a n n a n , states that neither the prothoracic plate, nor the legs, nor the long abdominal bristles serve in hatching. He mentioned that the prothoracic plate may serve to smoothen the sides of the gallery made by the mandibles of the penetrating larva. Brindley and Chamberlin (1952), working on *Bruchus pisorum*, assume that this plate no doubt helps the newly hatched grub in getting from the egg into the pea.

The pronotum does not show any divisions, while the meso- and metanotum are divided each into an anterior prescutum (Fig. 14, PRS) and a posterior scutoscuteillum (SC). This latter area carries a long bristle together with a very short one at its base. On the other hand, the pronotum is provided with three pairs of long bristles and two pairs of very short ones (Fig. 23).

The thoracic pleura are divided into the epipleura (Fig. 14, EPL) and the hypopleura (HPL). The epipleura of the pro- and mesothorax each carries a long bristle. The thoracic spiracles (SP. 1) open on the mesothoracic epipleura.

The thorax carries three pairs of legs (Fig. 14, LI, L2, and L3). At the base of each leg the sternum carries a long bristle. There are only two divisions in each leg (Fig. 24). The first one has two bristles at its distal end and the second is paddle-shaped at the extremity. These legs are greatly reduced as compared with those of *Acanthoscelides obtectus* larva. R a z z a u t i (1917), in this latter instance, gave the following measurements for the fore, the middle, and the hind legs: 0.07, 0.09 and 0.11 mm., respectively. In the larvae of *Bruchidius alfieri* and *Bruchidius trifolii*, the three pairs of legs are all equal, measuring 0.04 mm. in length. In the larvae of some bruchid beetles, as *Mylabris pruininus*, *M. limbatus* and *Zabrotes pectoralis*, the legs are completely absent (K u n h i K a n n a n , 1923).

Abdomen

The abdomen (Fig. 14, ABD) is composed of ten segments which are successively smaller towards the posterior end of the body. Each of the nine anterior abdominal segments is divided dorsally into two regions, anterior prescutum (PRS) and posterior scutoscuteillum (SC). This latter carries a very long bristle at the base of which there is another short one.

The pleuron of the first eight abdominal segments shows two divisions: upper epipleuron (EPL) and lower hypopleuron (HPL). In the ninth segment it is wholly represented by the epipleuron. Each of the abdominal segments, except the last two, carries a pair of spiracles which opens on the epipleuron. A well developed backwardly directed conical spine (S), characteristic of the bruchid larvae, is found on each side of the first abdominal segment above the spiracles (SP. 2). According to Z a c h e r (1930) its function seems, like the prothoracic plate, to serve as leverage during hatching.

M u k e r j i (1938) states that "the thrust necessary for rupturing the egg-sac, was obtained by driving the two conical spines of the first abdominal segment against the lateral walls of the egg-sac, and pushing forward the anterior end of the body : the anterior horns of the prothoracic plate rupture the egg-sac, and the seed coat is cut by the mandibles". On the epipleura of the second, third and fourth abdominal segments, below the spiracles, there is a very short bristle, whereas in the fifth to the ninth segments this is accompanied by a very long one similar to that of the scuto-scutellum. The hypopleuron (Fig. 14, HPL) does not carry any bristles, except for a very long one on the first abdominal segment.

The sternum (STN) of each of the first nine abdominal segments is provided with a small bristle ventrally. The tenth segment of the abdomen (ABD.10) does not present any divisions or carry any bristles.

2. Second, third, and fourth larval instars

These larval instars differ from the first one in the head and its appendages and also in the disappearance of such structures characteristic of the first instar, i.e. the prothoracic plate, the spine of the first abdominal segment, the bristles which are distributed over the body and the legs; only the legs become replaced by very short apparently useless conical prominences. The segmentation of the body is exactly similar to the that of first instar.

Apart from size and certain other morphological differences in the head appendages, the second, third, and fourth larval instars are very similar.

The epicranial suture is less developed than in the first instar, the coronal suture (Fig. 25, CN.S.) extends more anteriorly, while the frontal sutures have entirely disappeared. The head carries four bristles on its anterior end very near to the epistoma (EPS), which does not carry any bristles.

The antenna of the second and third instars (Fig. 26) is identical. It is composed of 2 segments, a broad basal segment (1) and a narrow digitiform distal one (2). The basal antennal segment carries a stiff short spine near its inner side, and a long bristle at the outer border. It carries also a short bristle together with a sensory pore. The antenna of the fourth instar (Fig. 27) is composed of two segments : a basal slightly chitinated segment (1) provided with three sensory pores, and an apical strongly chitinated one (2) having apically a corona of very small bristles. This last segment carries distally, a long digitiform process (3) together with two other bristles of different lengths.

The labrum of the second instar (Fig. 28) carries, distally, a row of four bristles along its anterior margin, and two other pairs posterior to them. At the posterior end of the labrum there is a chitinated plate which bears a pair of bristles and a pair of sensory pores. In addition to these, the labrum of

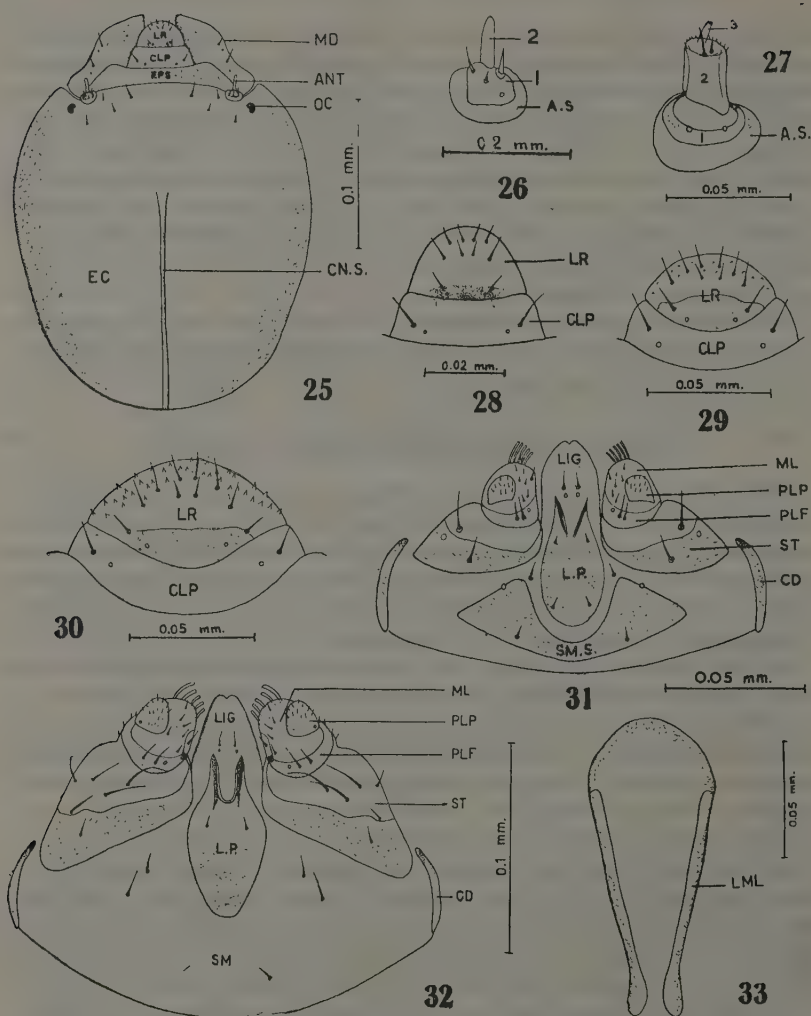


Fig. 25 : Head of the second larval instar, dorsal view (ANT, antenna; CLP, clypeus; CN.S., coronal suture; EC, epicranium; EPS, epistoma; LR, labrum, MD, mandible; OC, ocellus). — Fig. 26: Antenna of the second larval instar (A.S., antennal socket; 1 and 2, antennal segments). — Fig. 27 : Antenna of the fourth larval instar (A.S., antennal sclerite; 1, 2 and 3, antennal segments). — Fig. 28 : Labro-clypeus of the second larval instar (CLP, clypeus; LR, labrum). — Fig. 29 : Labro-clypeus of the third larval instar (CLP, clypeus; LR, labrum). — Fig. 30 : Labro-clypeus of the fourth larval instar (CLP, clypeus; LR, labrum). — Fig. 31 : Subfacial region of the second larval instar (CD, cardo; LIG, ligula; L.P., labial plate; ML, mala; PLF, palpifer; PLP, maxillary palp; SM.S., submental sclerite; ST, stipes). — Fig. 32 : Subfacial region of the fourth larval instar (CD, cardo; LIG, ligula; L.P., labial plate; ML, mala; PLF, palpifer; PLP, maxillary palp; SM, submentum; ST, stipes). — Fig. 33 : Hypopharynx of the fourth larval instar (LML, hypopharyngeal lamella).

the third instar (Fig. 29) carries very few small bristles along its anterior margin, these increasing in number in the fourth instar (Fig. 30).

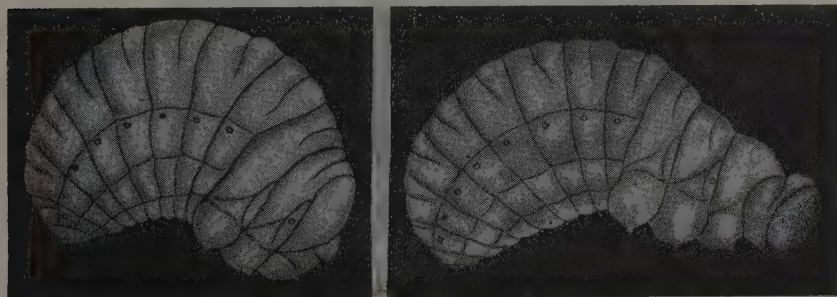
The epipharynx and mandibles are identical to those of the first instar. The maxillae consist also of the same parts, but differ in the distribution of bristles from one instar to the other, as shown in Figures 31 and 32.

The subfacial region is characterised, in the second instar (Fig. 31), by the presence of a well chitinised crescentic sclerite posteriorly. This is known as the submental sclerite (SM.S.), and it carries a pair of bristles and two sensory pores. The labial plate (L.P.) is much more pronounced than in the first instar and is deeply incised in the middle line anteriorly, thus presenting two anterior prongs. In the third and fourth instars, the submental sclerite is absent, the submentum (Fig. 32, SM) is entirely membranous.

The hypopharynx (Fig. 33) is membranous and shows on either side a long well chitinised hypopharyngeal rod (LML).

VII. Prepupa

At the end of the fourth stage (Fig. 34), the larva stops feeding and forms a cocoon into which it is changed into the prepupa. The wall of the cocoon lies immediately below the seed coat which is the only part left at the end of the larval period, all the cotyledonous tissue as well as the embryo being consumed by the developing larva. According to Skaife (1926) the cocoon is composed of silk, of excrement, and of a paste made of finely masticated food mixed with saliva. Herford (1935) observed a frothy and



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35

Fig. 34 : Fourth larval instar, lateral view. — Fig. 35 : Prepupa, lateral view.

milky fluid regurgitated from between the larval mandibles and plastered over the surface of the cell. She did not state definitely the source of this liquid. She also found, in the full grown larva, two sinuous chalky-white bodies, running nearly the whole length of the body and appearing to have

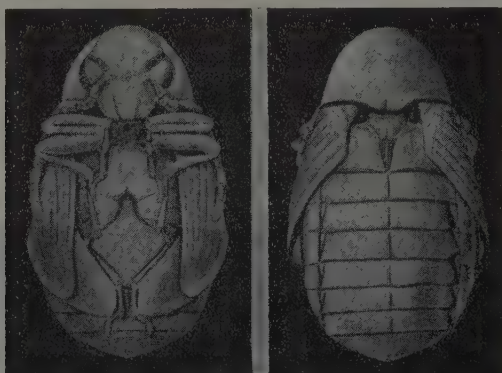
a connection with the buccal cavity. As they were not seen in the prepupa, it is assumed by her that they are connected with the formation of the cocoon.

The prepupa (Fig. 35) differs in shape from the last larval instar. The head protrudes from the prothorax and assumes a vertical position to the long axis of the body. So the mouth parts, which were directed anteriorly in the larva, become now directed ventrally. The abdomen is no longer curved ventrally, but it is stretched out straight in its posterior part.

VIII. Pupa

The pupa is white, oval in shape, with a smooth surface free from bristles or hairs. It is about the same size of the adult, measuring from 1.69 to 2.30 mm. in length, and 0.87 to 1.28 mm. in width.

In ventral view (Fig. 36), the head is inclined ventrally and bent beneath the prothorax. The mouth parts lie between the coxae of the first pair of legs. The eyes are prominent. The mandibles are distinct, the maxillary palps show a distinct segmentation and reach the second pair of legs. The



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Fig. 36 : Pupa, ventral view. — Fig. 37 : Pupa, dorsal view.

antennae curve laterally, pass behind the fore and middle legs, and come to lie again upon the elytra. Their segmentation is quite distinct. The striae of the elytra are very clear. The apical parts of the hind wings can be seen extending beyond the elytra. The fore and middle legs are equal; their femora and tibiae are folded horizontally above the elytra, while their tarsi are parallel to the long axis of the body. The hind pair of legs is covered for most of its parts by the wings, except parts of the coxae and the trochanters; the tarsi are all exposed and run along the inner border of the

apical parts of the hind wings, and reach almost to the base of the last abdominal sternite. In the early pupa, the segmentation of the legs is more or less obsolete, but later on it becomes quite distinct. Male and female pupae can be distinguished, as in the adults, by the shape of the last visible abdominal sternite which is more deeply emarginate posteriorly in the male than in the female. Specific pupal organs are not present.

In dorsal view (Fig. 37), the head is completely concealed by the prothorax. The three thoracic segments are well differentiated from each other. The prothorax is more or less triangular in outline, much wider posteriorly. The elytra are curved laterally and then pass to the ventral side. The abdominal segments are quite clear. Seven tergites can be seen, the anterior six of which are equal, while the seventh forming the pygidium is larger, triangular in shape and curved ventrally to fit against the last abdominal sternite. The spiracles of the abdominal segments 2-6 can be seen on the lateral sides of the tergites of the corresponding segments.

The pupa, when first formed, is white and translucent with no sign of chitinisation. The first sign of chitinisation appears in the eyes and is followed by the tips of the mandibles.

IX. SUMMARY

The present work deals with the biology of the berseem seed beetles, *Bruchidius trifolii* (Motsch.) and *Bruchidius alfierii* Pic. The results obtained have shown that they are not two different species, but belong to one and the same species.

The results of these studies are summarized as follows :

(1) Adults of *B. trifolii* are found all the year round. In winter they hibernate under fallen leaves or any suitable shelter in the field. In spring and in the beginning of summer they become very active, fly about over the blooming berseem plants, usually reaching sexual maturity at that time, and causing infestation to the new crop. In summer, it is found in the stores in small numbers, usually aestivating inside the seeds and then appearing in large numbers in the beginning of October.

B. alfierii is abundant in the field only during May and June. In the stores, it is available only during the period from June to September, manifesting itself in huge numbers. Adults of the *alfierii* form are always sexually mature after emergence.

(2) Breeding of *B. alfierii* took place successfully in the laboratory. Males and females started copulation soon after emergence. The resulting offspring consisted either of both forms or of one form only.

Trials to breed *B. trifolii* in the laboratory ended in vain since usually adults of this form do not attain sexual maturity, except in the field. In very

few individual cases however, inter-breeding between *alfierii* and *trifolii* occurred in the laboratory, and the offspring consisted of the *alfierii* form. It is therefore possible that some individuals of *trifolii* may reach sexual maturity in the store and hence inter-breeding may take place.

Adults possessing intermediate colour characteristics between both forms behaved in a similar way as *B. alferii* and mated either with themselves or with *B. alferii*.

All the following results on longevity, oviposition, fecundity, etc., were obtained from experiments on *B. alferii*.

(3) Males are long lived than females. At 32°C. and 50% R.H., the longevities were 3.7 and 8.7 days for the females and males, respectively. Humidity seems to have a very slight effect on the duration of the adult life; on the other hand, the effect of temperature is much more pronounced, increase in temperature shortens the adult life.

Unmated individuals lived longer than mated ones, those copulating once lived longer than those copulating several times, and delayed fertilization caused also an increase in longevity.

Food seems to have a marked influence on the length of the adult life; honey, sugar solution or water cause an increase in longevity.

(4) Eggs are laid on the seeds and attached to their coats by means of a glutinous substance secreted prior to oviposition.

Seeds seem to act as stimulus to egg laying since the number of eggs laid in presence of seeds greatly exceeded that laid in their absence. Sound seeds are preferred to injured ones for egg laying.

(5) At 32°C. and 50% R.H., the pre-oviposition period is 3 to 4 hours. Changes in temperature have a slight influence on the duration of that period, e.g. at 28 and 23°C., it is slightly prolonged but always less than one day; at 16°C. it lasted for about two days, sometimes reaching a maximum of nine days. Humidity, on the other hand, seems to have no effect on that period.

Mating also affects the pre-oviposition period. In unmated females oviposition was delayed for an average of one to three days at 32°C. and 50% R.H.

(6) The average total number of eggs laid per female is about 52.2 eggs at 32°C. and 50% R.H. This seems not affected by changes in the relative humidity or in temperature except at 16°C., where the number of eggs is reduced to about half that laid at any of the three other temperatures used, i.e. 23, 28 and 32°C.

Unmated females lay significantly smaller number of eggs (33.1 on the average) compared with mated ones. These eggs are unfertile and collapse after deposition.

The number of eggs laid by females copulated once is slightly less than

that laid by several times copulating females. Delayed fertilization also affected slightly the total number of eggs laid.

The average total output of eggs varied with respect to differences in food, increasing steadily from beetles receiving nothing (49.3 on the average) to those receiving water (50.4 on the average), then to those given sugar solution (54.6 on the average), and lastly to those fed on honey (64.4 on the average).

(7) At such temperatures as 23, 28 and 32°C., the female lays the greatest number of eggs on the first day of its life, then the number decreases gradually as the female advances in age. This is also the case with females given different foods. On the other hand, at such a low temperature as 16°C., there was no regularity in the oviposition rate, and there were intervals of some days during which no eggs were laid.

Unmated females lay very few eggs at first, then the number increases steadily to reach its maximum on the fourth day, and then decreases gradually on the following days.

(8) The sex ratio is nearly 1:1, with slight preponderance of females.

(9) Eggs laid by unmated females were unfertile and failed to hatch. At 32°C. and 50% R.H. the eggs required 5.1 days to hatch. Changes in temperature seem to affect greatly the incubation period, increasing with decrease of temperature from 32 to 23°C. At 16°C., no hatching took place.

(10) After hatching, the larva bores directly into the seed from the egg shell and passes all its subsequent life inside it, transforming to pupa and finally emerging from the seed as adult. Therefore, it has not been possible to study these two stages separately. At 32°C. and 50% R.H., the duration of the larval and pupal stages is 15.5 days on the average. Changes in the relative humidity slightly affect the duration of these stages. The effect of temperature, on the other hand, is much more pronounced; lowering the temperature causes a prolongation of this duration. Unlike the eggs, 16°C. was not fatal to the larva.

(11) Four larval instars are distinguished on account of differences in the width of the head capsule and also in the mouth parts. There exists hypermetamorphosis in the development of both *Bruchidius trifolii* and *B. alferii* as the first stage larva differs in certain morphological features from the following stages.

REFERENCES

- A b o u - R a y a , A.K. (1954) : *Bruchidius alferii* Pic, a biologic race of *Bruchidius trifolii* Mostch. (Bull. Soc. Fouad I Ent., XXXVIII, pp. 193-203).
- A n d e r s o n , W.H. (1936) : A comparative study of the labium of Coleo-

- pteros larvae (Smithson. misc. coll. (Washington), XCV, no. 13, 29 pp., 8pls.).
- B a c k, E.A. (1940) : Weevils in beans and peas (*Farmer's Bull.* (U.S. Dept. Agric.), no. 1275, 35 pp.).
- B a u d i, F. (1886) : Mylabridum seu Bruchidum (*Deutsche Ent. Zeitschr.*, XXX, p. 416).
- B a u d i, F. (1887) : Mylabridum seu Bruchidum europeae et finitimarum regionum Faunae recensio (*Deutsche Ent. Zeitschr.*, XXXI, pp. 460-461).
- B o v i n g, A.G. (1927) : On the classification of the Mylabridae larvae [Coleoptera : Mylabridae] (*Proc. Ent. Soc. Wash.*, XXIX, pp. 133-142).
- B o v i n g, A.G., and C r a i g h e a d, F.C. (1931) : An illustrated synopsis of the principal larval forms of the order Coleoptera (*Ent. Amer.* (Brooklyn), XI, pp. 1-351).
- B r i d w e l l, J.C. (1932) : The subfamilies of the Bruchidae [Coleoptera] (*Proc. Ent. Soc. Washington*, XXXIV, pp. 100-106).
- B r i n d l e y, T.A. (1933) : Some notes on the biology of the pea weevil *Bruchus pisorum* L. (Coleoptera, Bruchidae) at Moscow, Idaho (*J. econ. Ent.* (Geneva, N.-Y.), XXVI, pp. 1058-1062).
- B r i n d l e y, T.A., and C h a m b e r l i n, J.C. (1952) : The pea weevil (Year-book U.S. Dept. Agric., pp. 530-537).
- B u s h n e l l, R.J., and B o u g h t o n, D.C. (1940) : Longevity and egg production in the common bean weevil, *Acanthoscelides obtectus* (Say) (*Ann. Ent. Soc. Amer.*, XXXIII, pp. 361-370).
- B u x t o n, P.A., and M e l l a n b y, K. (1934) : The measurement and control of humidity (*Bull. Ent. Res.*, XXV, pp. 171-175).
- C h i t t e n d e n, F.H. (1898) : Insects injurious to beans and peas (Year-book U.S. Dept. Agric., pp. 233-260).
- D a v i a u l t, L. (1928) : Sur le développement post-embryonnaire de la bruche du haricot : *Acanthoscelides obtectus* Say, suivi de considérations sur la signification phylétique de son dimorphisme larvaire (*Ann. Soc. ent. Fr.*, XCVII, pp. 105-132).
- E m d e n, F.I. van (1946) : Egg-bursters in some more families of polyphagous beetles and some general remarks on egg-bursters (*Proc. R. ent. Soc. London* (A), XXI, pp. 89-97).
- F i s h e r, R.A., and Y a t e s, F. (1948) : Statistical tables for biological, agricultural and medical research (Oliver and Boyd Ltd., London and Edinburgh, third edition).
- H a f e z, M., and O s m a n, M.F.H. (1954) : Notes on the biology of *Bruchidius trifolii* Mots. and *Bruchidius alfieri* Pic (*Ann. Mag. Nat. Hist.*, Ser. 12, VII (January), pp. 63-64).
- H e r f o r d, G.M. (1935) : Observations on the biology of *Bruchus obtectus* Say.

- with special reference to the nutritional factors (*Zeits. angew. Ent.* (Berlin), XXII, pp. 26-50).
- Hoffmann, A. (1945) : Coléoptères Bruchides et Anthribides (Faune de France, XLIV, 148 pp., 382 figs., Paris, Lechevalier).
- Imms, A.D. (1948) : A general text-book of Entomology (Methuen and Co. Ltd., London, 7th edition).
- Kunhi Kannan, K. (1919) : Pulse beetles (Store forms) (Mysore State Dept. Agric. (Bangalore), Ent. Ser., Bull. 6, 31pp.).
- Kunhi Kannan, K. (1923) : The function of the prothoracic plate in Mylabrid (Bruchid) larvae (a study in adaptation) (Mysore Dept. Agric. (Bangalore), Ent. Ser., Bull. 7, 47 pp.).
- Larson, A.O., Brindley, T.A., and Hinman, F.G. (1938) : Biology of the pea-weevil in the Pacific Northwest, with suggestions for its control on seed peas (U.S. Dept. Agric., Tech. Bull. no. 599, 48pp.).
- Larson, A.O., and Fisher, C.K. (1924) : Longevity and fecundity of *Bruchus quadrimaculatus* Fab. as influenced by different foods (*J. Agric. Res.*, XXIX, pp. 297-305).
- Larson, A.O., and Fisher, C.K. (1938) : The bean weevil and the southern cowpea weevil in California (U.S. Dept. Agric., Tech. Bull. no. 593, 70 pp.).
- Larson, A.O., and Simmons, P. (1923) : Notes on the biology of the four-spotted bean weevil, *Bruchus quadrimaculatus* Fab. (*J. Agric. Res.*, XXVI, pp. 609-616).
- Lepesme, P. (1942) : Sur l'éclosion et le comportement de la larve néonate chez *Acanthoscelides obsoletus* Say (Col., Bruchidae) (*Bull. Soc. ent. France*, XLVII, pp. 7-9).
- Marcucci, E. (1920) : Osservazioni sulla forma esterna e sulla biologia della larva di *Acanthoscelides obtectus* (Say) (*Arch. Zool. Ital.* (Napoli), IX, pp. 237-261).
- Menusan Jr., H. (1934) : Effects of temperature and humidity on the life processes of the bean weevil, *Bruchus obtectus* Say (*Ann. Ent. Soc. Amer.*, XXVII, pp. 515-526).
- Menusan Jr., H. (1935) : Effects of constant light, temperature and humidity on the rate and total amount of oviposition of the bean weevil, *Bruchus obtectus* Say (*J. econ. Ent.*, XXVIII, no. 2, pp. 448-453).
- Menusan Jr., H. (1936) : The influence of constant temperatures and humidities on the rate of growth and relative size of the bean weevil, *Bruchus obtectus* Say (*Ann. ent. Soc. Amer.*, XXIX, pp. 279-288).
- Motschulsky (1873) : *Bull. Mosc.*, XLVI (1874), p. 235.
- Mukerji, D., and Hakim Bhuya, M.A. (1937) : Reproductive system of the Bruchid beetles *Bruchus quadrimaculatus* Fabr., *Bruchus (Callosobruchus) chinensis* L. (Bruchidae, Coleoptera) (*J. Morph.* (Phila-

- delphia), LXI, pp. 175-214).
- Mukerji, D. (1938) : Anatomy of the larval stages of the Bruchid beetle *Bruchus quadrimaculatus* Fabr., and the method of emergence of the larva from the egg-shell (*Zeits. angew. Ent.* (Berlin), XXV, pp. 442-460).
- Paddock, F.B., and Reinhard, H.J. (1919) : The cowpea weevil (Texas Agric. Expt. Sta., College Station, Bull. 256, 92 pp.).
- Peterson, A., and Haussler, G.J. (1928) : Some observations on the number of larval instars of the oriental peach moth, *Laspeyresia molesta* Busck. (*J. econ. Ent.*, XXI, no. 6, pp. 843-852).
- Pic, M. (1913) : *Coleopterorum catalogus* (ed. Schenkling), Pars 55 : Bruchidae, pp. 1-74.
- Pic, M. (1922 (1923)) : Sur divers Coléoptères intéressants ou nouveaux d'Egypte (*Bull. Soc. R. Ent. Egypte*, VII, pp. 95-104).
- Razzauti, A. (1917) : Contributo alla conoscenza del tonchio del fagiolo (*Acanthoscelides obtectus* Say) (*Boll. Lab. Portici*, XII, pp. 94-122).
- Richards, O.W. (1947) : Observations on grain weevils, *Calandra* (Col., Curculionidae) : 1. General Biology and Oviposition (*Proc. Zool. Soc. London*, CXVII, pp. 1-43).
- Riley, C.V., and Howard, L.O. (1892) : The pea and bean weevils (*Insect Life*, IV, pp. 297-302).
- Roberts, A.W.R. (1930) : A key to the principal families of Coleoptera in the larval stage (*Bull. Ent. Res.*, XXI, pp. 57-72).
- Schilsky (1905) : Die Käfer Europas (Heft 41, nr. 82).
- Schoof, H.F. (1941) : The effects of various relative humidities on the life processes of the southern cowpea weevil, *Callosobruchus maculatus* (Fabr.), at 30°C. \pm 0.8°. (*Ecology* [Lancaster, Pa.], XXII, pp. 297-305).
- Skaife, S.H. (1918) : Pea and bean weevils (Union S. Afr. Dept. Agric., Bull. 12, 32 pp., illust.).
- Skaife, S.H. (1926) : The bionomics of the Bruchidae (*S. Afr. J. Sci.* (Pretoria), XXIII, pp. 575-588).
- Solomon, M.E. (1951) : Control of humidity with Potassium hydroxide, Sulphuric acid or other solutions (*Bull. Ent. Res.*, XLII, pp. 543-554).
- Steffan, J.R. (1945 (1946)) : Contribution à l'étude de *Zabrotes subfasciatus* Boheman (*Mém. Mus. Hist. nat.* (Paris), XXI (N.S.), pp. 55-84).
- Steffan, J.R. (1946) : La larve primaire de *Bruchidius fasciatus* Ol. et ses rapports avec quelques larves néonates des Bruchides (*Bull. Soc. Ent. France*, LI, pp. 12-16).
- Uvarov, B.P. (1931) : Insects and climate (*Trans. Ent. Soc. London*, LXXIX, pp. 1-247).
- Vukasovich, P. (1949) : Facteurs conditionnels de la ponte chez *Acanthoscelides obtectus* (*Bull. Mus. Hist. nat. Pays Serbes*, Belgrade (B), no. 1-2, pp. 223-234, in Serbian, with French summary).

- Willcocks, F.C. (1922) : A survey of the more important economic insects and mites of Egypt (*Bull. Sultanic Agric. Soc.* (Cairo), No. 1, pp. i-viii and 1-483).
- Willcocks, F.C., and Bahgat, S. (1937) : Insects and mites injurious to the cotton plant (The Insects and related pests of Egypt, I, part 2, Royal Agric. Soc., Cairo).
- Williams, C.B. (1937) : The use of logarithms in the interpretation of certain entomological problems (*Ann. appl. Biol.*, XXIV, no. 2, pp. 404-414).
- Zaazou, H. (1948) : The longevity of the bean weevil : *Acanthoscelides obsoletus* Say (Coleoptera : Bruchidae) (*Bull. Soc. Fouad Ier Ent.*, XXXII, pp. 51-70).
- Zaazou, H. (1948) : Oviposition of the bean weevil : *Acanthoscelides obsoletus* Say (Coleoptera : Bruchidae) (*Bull. Soc. Fouad Ier Ent.*, XXXII, pp. 343-361).
- Zacher, F. (1929) : Nahrungsauswahl und Biologie der Samenkafer (*Verh. deuts. Ges. angew. Ent.*, 7 Versamml. (1928), pp. 55-62).
- Zacher, F. (1930) : Untersuchungen zur Morphologie und Biologie der Samenkafer (Bruchidae-Lariidae). Beitrage zur Kenntniss der Vortrschadlinge. (6). Beitrag (*Arb. Biol. Reichsanst. Land- u. Forst.* (Berlin), XVIII, pp. 233-384).
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Studies on Desert Insects in Egypt

I. FIELD AND LABORATORY INVESTIGATIONS ON THE WORM-LION, *VERMILEO VERMILEO* L.

[Diptera : Rhagionidae]

(with 14 Text-Figures)

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I. INTRODUCTION

Studies on desert insects have received but little attention in Egypt in spite of the fact that the desert occupies almost nine tenths of the Egyptian territory. This may be due to the fact that most workers in this country have laid more emphasis on insects of agricultural or of medical importance.

The desert contains a vast variety of insects, most of which are remarkably adapted to resisting and surviving such severe environment where food and water are scarce. These insects, no doubt, provide an excellent medium for biological, ecological and physiological research.

In view of this and of the fact that very little is known about the insects of Egyptian deserts, it was found advisable that a series of biological investigations on desert insects be started in the Department of Entomology, Faculty of Science, University of Cairo.

The present work deals with the larva of *Vermileo vermileo* L., perhaps the most interesting of all desert insects in this country.

The authors are greatly indebted to Professor H.C. Efflatoun, former head of the Entomology Department, Faculty of Science, University of Cairo, for suggesting the point and for his keen interest in the progress of the work. Thanks are also due to Professor H. Priesner, Dr. S. El-Ziady, and Mr. A. Alfieri for their valuable assistance.

II. GEOGRAPHICAL DISTRIBUTION

The first observer (an Anonymous) of *Vermileo* cited no precise locality for his specimens, but the insect was later recorded by different authors from the following localities (Wheeler, 1931) :

Near Lyon at Palud in the Provence and in the Auvergne (Rebory (Reaumur, 1753)); park of Vernon near Tours (De Romand, 1833) ; Camaldoli near Naples and on the Island of Ischia (Costa, 1844); the Landes (Perris, 1852); Calabria (Costa, 1863) ; probably near Saumur, in the Department of Maine-et-Loire (Courtilier, 1867); in the "Glimmersand" of the garden of the Franciscan monastery at Bozen in Southern Tyrol (The friar Gredler); *loc. cit.*, also from the Trudener Thal, near Neumarkt (Palm, 1869); Island of Lessina in Dalmatia (Mik, 1887); *loc. cit.* (Novak); botanical garden of Milan (Bezzi, 1898); at Bra in Piedmont (Griffini, 1895); Parma (Rondani); Rome (Barbiellini); peninsular Italy (Bezzi, 1898); near Madrid and in Catalonia and Aragon (Navas, 1913); Bosen (Th. Becker, 1921-22).

In Egypt, in 1924 and 1925, Professor H.C. Efflatoun and Dr. C.B. Williams, came across the larvae of *Vermileo vermileo* in Wadi Digla, beneath the sloping under-surfaces of over hanging limestone cliffs. Moreover, Professor Efflatoun found the larvae in Wadi El-Tih and Wadi Gandali (Eastern Desert, between Cairo and the Gulf of Suez). Falcoz (1927) found the larvae in Dauphiné, in dry powdery soil along a wall protected by a parapet (Wheeler, 1931). Wheeler (1931) obtained some larvae during the summer of 1925 on the balearic Islands Majorca and Minorca and near Cole de Sollar. He found them in the North-Western mountainous portion (Jurassic limestone) of Majorca and on the 18th to 23rd kilometer stone from Palma to Banalbufer, at first among the neolithic monuments at Talati where the larval pits were made in the dust under the projecting edges of some of the monoliths. Wheeler stated that the Minorcan custom of enclosing all the small fields with stone walls 6 to 8 feet high, with accumulated dust in their crevices affords a favourable environment for *Vermileo* colonies. He added that more of the larvae were found under the cliffs of limestone bordering some of the many barrancos which extend down to the sea mainly the Barrancos Simon, San Juan and Calempor. Buchner (1940) found the larvae of *Vermileo vermileo* on the island

of Ischia in the Gulf of Naples.

These records show that the distribution of the insect extends over a large part of Spain Central and Southern France, the whole Italy, Southern Tyrol, Dalmatia, the Balearic Islands and Egypt.

III. REVIEW OF LITERATURE

C.B. Williams (1923-1924a) was the first to describe in detail the region of Wadi Digla in his series of extensive bioclimatic investigations. He studied the variations in temperature, humidity and other environmental conditions in sun and shade, under rocks, in caves and in various depths in the soil. Apart from these studies, no solid work in relation to entomology in the Egyptian deserts has been undertaken.

Concerning the habits of the larva, the worm-lion was not known until the beginning of the eighteenth century when it was first described in the reports of the Royal Academy in 1706 by a French Anonymous. About fifty years later, the insect attracted the attention of Reaumur, who was the first to name the insect "Verlion", and De Geer, who published an illustrated account in 1752 of the habits of this insect to which he referred as "Sandmasken" or "mask-lejonet". About 100 years later, this insect again aroused the interest of entomologists such as von Siebold (1861), who studied its feeding habits. But the knowledge about the worm-lion remained rather fragmentary and inadequate until the American ant-specialist Wheeler (1931), published in his "Demons of the dust" a comprehensive account of ant-lions and worm-lions. He gave few hints on the biology of *Vermileo vermileo* and studied in some detail the structure and behaviour of the immature forms of the Sierra worm-lion *Vermileo comstocki*. In addition, he reported on the worm-lions of the genus *Lampromyia* and the worm-lions of Indonesia.

The morphology of the larvae of some Rhagionids was dealt with by Brauer (1883), Meijere (1916), Malloch (1917), Engel (1929), Greene (1926), Vimmer (1931), Wheeler (1931), and Pechuman (1938).

IV. MATERIAL, METHODS, AND TECHNIQUE

For studying the insect in its natural habitat, several excursions were made to Wadi Digla and the surrounding wadies. The way to these wadies is so rocky and uneven that a jeeb was always used for reaching the place. Records were taken hourly from 10 a.m. to 4 p.m. Dry and wet bulb hygrometers were used for measuring the relative humidity of the air. Three thermometers were placed in the sand at depths 2, 3, and 5 cm., very near to the site of larvae.

Several photographs of the rocks and larval pits in their natural habitat were taken.

A live stock of larvae was raised and maintained in the laboratory throughout the year. Larvae were obtained from Wadi El-Tih and Wadi Digla. The sand around the pits was shovelled from beneath then sieved carefully and the larvae were separated and collected.

A few hundreds of glass tubes, each 10×3.5 cm. and a number of small carton boxes and rounded museum jars were all set and provided each with a suitable quantity of sand. Each tube contained a single larva, whereas the boxes harboured batches, each of twenty. In the jars numerous larvae were placed to study their behaviour in an artificial colonial form similar to the natural one.

The whole mount of the larva was drawn from "liquide de Faure". Permanent preparations stained with acid fuchsin were made for the different parts of the larva. The internal systems were examined from preparations stained with borax carmine with the exception of the respiratory system which was drawn from glycerine. The alimentary canal was better dissected from Ringer's solution.

V. THE NORMAL ENVIRONMENT OF THE LARVA

A. Locality

South-east of Cairo there is a vast extensive area in the form of an elevated plateau of middle Eocene limestone. This plateau is highly dissected by several valleys or wadies. Its surface is covered with powdered gypsum in certain places and is usually blackened by the so-called desert varnish. Rain pits are common and constitute a distinct surface feature. Of the wadies, Wadi Digla, Wadi El-Tih (or Wadi Belama), Wadi Gendali, Wadi Hof, Wadi Rachid, Wadi Hammadol and Wadi El-Racham are worthy of mention. These are bordered by steeply inclined or vertical cliffs which contain numerous abrupt steps that give rise to water falls during the rainy season. The cliffs are limestone and these together with the fine sand derived from them are of light sandy colour.

Vermileo colonies occur mainly in Wadi Digla, Wadi El-Tih and Wadi Gendali. The first two wadies run parallel to each other and are separated by many chains of rocks. Wadi El-Tih leads near its end to Wadi Gendali which is about 30 kilometers south-east of the "kilometer 51" on the Suez road.

Wadi Digla (Fig. 1) is about eighteen kilometers south-east of Cairo. It is in the form of a narrow ravine running through the limestone plateau to the east of the Nile. It was once a water course but now it is dry and extends for about fourteen kilometers. At the mouth of the wadi there is a

well named "Bir Digla", of about three metres diameter and is usually full of water.

Most of the field studies of the present work were mainly carried out in Wadi Digla, however some observations were made in Wadi El-Tih.

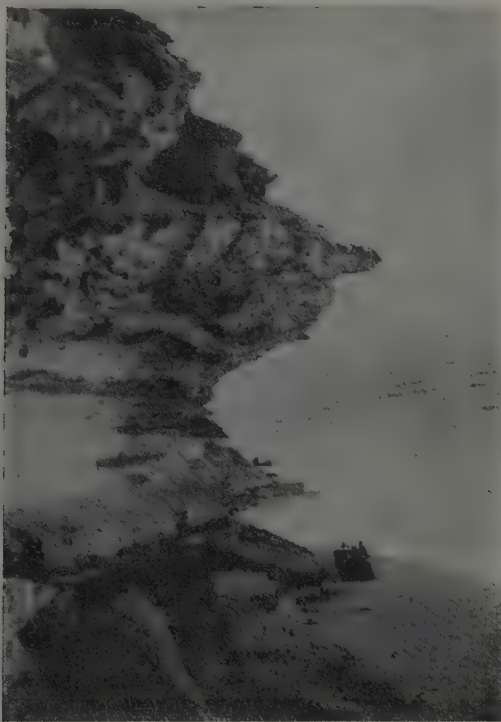


Fig. 1 : Part of Wadi Digla with overhanging rocks under which *Vermileo* colonies were found.

The colonies of *Vermileo* larvae are sporadically distributed at various places of the Wadi from its top to its bottom, but they are mostly concentrated and more abundant at a spot lying about four kilometers from the bottom of the wadi. At this spot, which is about ten kilometers far from the nearest cultivation which is an agricultural land on the bank of the Nile, and also about the same distance far from the Helouan observatory, all records were taken. The valley, at this spot, is about 200 metres above the sea level, 25 metres wide at the bottom, and about three times as much at the top. Wheeler (1931) stated that the mediterranean worm-lion *Vermileo vermileo*

lives at low elevations and even at sea level.

Opposite to our observation centre in the Wadi, there is a cave lying highlt nearly at the top of the rock.

Willia ms (1924) gave a detailed list of the plants, birds and insects that he found in Wadi Digla during his excursion in December 1923.

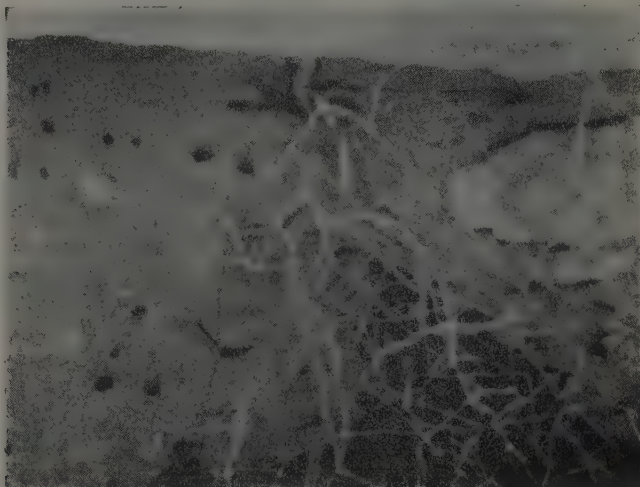


Fig. 2 : A colony of *Vermileo vermileo* in its natural habitat, showing the conical pitfalls of the larvae among patchy vegetation.

Vermileo vermileo larvae live in pits in the sand (Fig. 2), and are usually aggregated in groups commonly known as colonies. These colonies are scattered all over the Wadi, but they are dense and more numerous in certain localities.

The localities where *Vermileo* colonies are found are very characteristic in shape, structure, direction and sand consistency. It was noticed that the sand harbouring these colonies is mainly of fine nature.

Larval pits are generally found under overhanging cliffs (Fig. 1 and 3) that have a northern or north-western direction. They are not found under rocks with southern direction. This may be due to the fact that in the first position the larval pits are always in the shade sheltered from the direct unfavourable effect of the sun. Furthermore, the rocks protect the pits from rain and wind. This is supported by the fact that although a heavy rain fell on the wadi in December 1951, the sand in which the larvae constructed their pits was completely dry, while the rest of the wadi was wet. It seems



Fig. 3 : A step projecting from the rocks at a level of about 0.75 metre on which the larvae construct their pits far from rain.

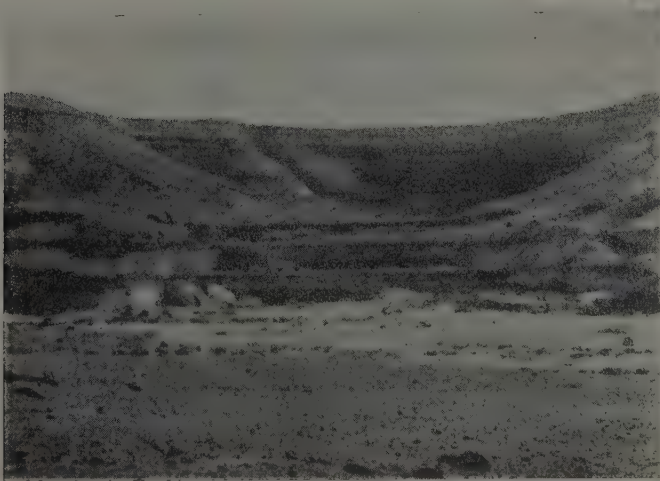


Fig. 4 : A loop within the chain of rocks providing suitable protection for *Vermileo* colonies.

also for this reason that the larval pits are usually found on steps of rocks (Fig.3) at a level about one metre from the bottom of the Wadi, or close to the bases of cliffs beside pieces of stones or large solid objects, or even in cavities of big fallen stones that happened to be filled with fine sand. They also construct their colonies within large loops of the chain of rocks (Fig. 4). All these situations seem to provide protection for larvae from the sun, heat, accumulated rain, and also from the direct effect of wind. These protective measures against adverse physical conditions seem to be a necessity, as the larvae are completely dependent upon their pits in obtaining their food supply.

Sometimes the larval pits occur among patchy vegetation as shown in Figure 2.

B. Climatic conditions

1. Rain

Generally speaking, rain is very scarce throughout the year in Wadi Digla. During 1952, rain fell on six days in February, October and December; and the total amount of rain fall was 10.6 mm.; while during 1953 the number of rainy days was about six times greater, but the total amount of rainfall was distinctly less, being 6.9 mm.

2. Temperature

Williams (1924) stated that the mean daily range of shade temperature in Wadi Digla is not as great as one usually associates with desert conditions.

During the years 1952 and 1953, the shade temperature reached a minimum in January of both years, being 4.2 and 4.9°C., respectively. On the other hand it reached its maximum in May 1952 and in June 1953, being 43 and 43.5°C., respectively.

The average monthly mean temperature during the years 1952 and 1953 are shown in Figure 5. This average was lowest in January of both years and highest in August 1952 and in July 1953.

3. Humidity

The relative humidity during the years 1952 and 1953 was the lowest in May. From May to December, a steady increase was observed, and as the temperature became higher during the spring, an obvious fall in the relative humidity was recorded.

4. Larval micro-climate

In the field the larvae lie in the bottom of their conical pits at depths

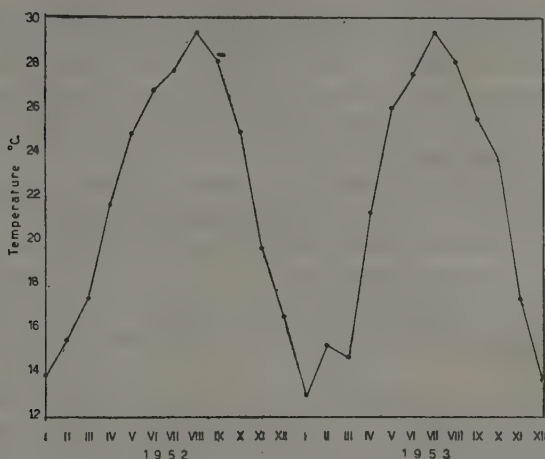


Fig. 5 : Average monthly mean temperature during the year 1952 and 1953 in the region of Wadi Digla.

varying from a few millimetres to about 3 cm., according to the size of the larva. For recording the sand temperature, three thermometers were dipped in the sand at depths of 2, 3 and 5 cm., very near to the site where the larvae live. The thermometers were left at these levels from 10 a.m. to 4 p.m., and the temperature was recorded hourly. It was found that the sand temperature at all depths varied within very small limits, which was only about one degree or even less in most cases. When comparing the sand temperature with the air temperature in the shade, it was found that the temperature of the sand was considerably lower than the shade temperature. On relatively cold days, the temperature of the sand was from one to two °C. higher than that in the shade. Also, the difference between the maximum and minimum temperature of the sand was smaller than the corresponding one of the air temperature in the shade.

From these observations one may suggest that the larvae in their natural habitat are subjected to a very small amount of environmental fluctuations.

It can also be mentioned that the surface sand temperature in areas exposed to the sun was 15 to 20°C. higher than the corresponding shade temperature.

VI. HABITS OF THE LARVA AND LARVAL FOOD

The larvae of *Vermileo vermileo* live in pits which they dig in the sand. They have the habit of living in clusters and dig their pits close to each other (Fig. 2), a habit which was also observed in nature.

The newly hatched larva is about 2.2 mm. in length and nearly three times as long as the egg in which it was confined. It is very active and makes several pores on the surface of the sand as if it were searching for a suitable position to construct its pits. One day or so after hatching, the conical pit has been formed by the small larva. The pit measures about 2 mm. in diameter and about the same in depth.

Larvae hatching at higher relative humidity, i.e. 70 and 90% could not penetrate through the sand, the latter being compact and wet.

The larva normally crawls on its back when moving from one place to another. If it is mechanically stimulated, it leaps in the air for several centimetres. Such leaps are frequently observed when the larva tries to escape capturing by another similar larva into whose pit it has accidentally fallen.

If the larva is sieved from the sand, it usually lies on its side bent in the form of the letter U (Fig. 6). It remains absolutely motionless in this position for a while looking as if it were completely dead. If such larva is again placed on the surface of the sand, it resumes its activities after few minutes. This phenomenon of death feigning has also been recorded from other worm-lions (Wheeler, 1931).

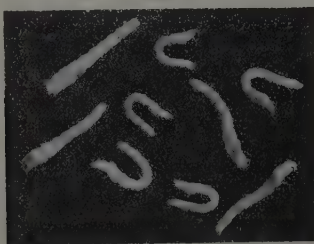


Fig. 6 : Larvae of *Vermileo vermileo*.

When ready to dig its pit, the larva crawls on the sand with the ventral surface upwards, and penetrates the sand first with its anterior extremity while the rest of the body pokes into the sand assuming at the same time a position which forms an acute angle with the surface. It then pushes itself gradually into the hole formed till it completely disappears. The ventral surface, during this process, is always directed upwards. When the larva completely vanishes underneath the surface of the sand, it then starts digging its pit. In doing so, it strongly curves the anterior part of the body on the abdomen, then thrusts it into the sand and elevates the head rapidly throwing off the sand particles. The larva repeats this action in all directions around

it and the result is the formation of the characteristic funnel-shaped pitfall, the natural abode of the larva and in which it traps its victims.

The diameter of the larval pit varies from a few millimetres to about 2.5 cm., according to the age and size of the larva.

The larva is negatively phototactic. During the day it lies at the bottom of its pit covered by a thin layer of sand. If the larva is placed in a dark room for a long time, it can be seen at the bottom of its pit. When suddenly exposed to day light, it will try immediately to cover itself again by shovelling a layer of sand over its body. Also most of the larval activities are carried out during the night.

The activities of the larva amount to repairing and cleaning the old pit or digging another if the old one becomes unsuitable, and it is interesting to watch at night, by the help of an electric torch, the laborious larvae in a cluster, actively digging and repairing their pits.

The larva is also positively geotactic, though in a restricted way. This is shown by the fact that when the larva is sieved or placed on a sieve, it immediately makes its way downward through the meshes of the sieve. This is supported by the behaviour of the larva when placed on the surface of the sand, as it always bores through it to construct its pit.

The larvae sometimes leave their pits at night and wander about. This is indicated by the long sinuous tracks which are observed on the surface of the sand.

It is noteworthy that the first stage larvae behave more or less in the same manner as the older ones. They assume the characteristic U-shaped posture, feign death, penetrate in the sand, construct pits and make several leaps when mechanically irritated, exactly like the mature larva, except that the former is relatively more active.

In the field, it was observed that most larvae tend to construct their pitfalls close to solid objects, for example at the bases of rocks and beside fallen stones. The same behaviour was noticed in the laboratory where the larvae usually constructed their pits beside the walls of dishes and glass tubes.

Wheeler (1931) is of the opinion that the peculiar tendency of the larvae to dig their pits close to rocks is not merely for sheltering from physical factors, but for the abundant food supply they may get in these situations. This is because he noticed that in the Yosemite valley, where *Vermileo comstocki* larvae were found, the ant *Liometopum occidentale*, a possible prey of *Vermileo*, had the habit of crossing the rock at its base near the pits of *Vermileo* larvae. This does not seem to be the case in *Vermileo vermileo* as it was noticed that :

1. Larval pits were mostly met with in the field close to rocks in shaded areas and not in sunny situations.

2. A number of larvae whose pits were found a little further from the

bases of rocks, i.e. in the open were always still in the shade.

3. Ants which were abundant in other places crossing the rocks at their bases, were not observed in wadies where *Vermileo vermileo* larvae live.

Therefore, it seems that in the case of *Vermileo vermileo*, the abundance of food plays no part in attracting the larvae to build their pits close to rock bases, but protection against adverse physical conditions such as strong light, excessive heat, strong wind, rain, etc., is most probably the main factor influencing the larvae to choose such sheltered situations as their abodes.

When the larva is in its pit awaiting a prey, it lies horizontally and motionless at the bottom with the greater part of the posterior end of its body anchored into the sand.

In their natural habitat, the larvae were found to feed mainly upon small insects such as aphids, ants, termites and other small soft-bodied animals that may fall accidentally in their pits. It seems also that the larvae derive their water requirements from their preys. It is therefore clear that securing food and water by the larvae is entirely left to chance and consequently the larvae may remain for months without food or drink. The same was also recorded from the Stratiomyid fly, *Hermetia chrysopila*, whose larvae eat decayed cactus joints and can resist lack of food and water at least fifteen months (Buxton, 1923).

In the laboratory, larval food consisted mainly of small insects. The first stage larva was found to feed readily on small nymphs of aphids such as *Aphis gossypii* and *Rhizobius graminis*. These were usually thrown directly in the larval pits. The advanced larvae also accepted aphids and small flies, such as *Drosophila*, chironomids and mosquitoes together with small caterpillars, when offered to them.

The larva has a peculiar habit in siezing and eating its prey. The victim, while walking on the sand, slips into the larval pit if it comes across, and this means its end because immediatly the larva usually increases the steepness of the walls of its pit by removing some sand in order to make it difficult for the prey to climb upwards, thus preventing its escape. Then the larva takes a suitable hold of the prey, so that the latter causes no annoyance to it by the mouth parts or legs. If the prey be an ant, its waist will be surrounded by the head and the anterior segments of the larval body, thus paralysing it. The body fluid of the victim is then sucked by the larva, whereas the remains are casted off outside the pit. Meanwhile, some repairs are made in the latter, in preparation for the next victim.

The larval resistance to lack of food and water is very remarkable, and differs mainly according to age. Thus, the first stage larva can resist lack of food for about three months, while older ones for about twelve months. During this period of starvation, the larvae assume their normal activitise and are often seen constructing and repairing their pits.

As regards the enemies of the worm-lion in its natural habitat, it is probable that it suffers from cannibalism, especially that in nature the larvae are aggregated in colonies and are thus within the reach of each other. As was shown from laboratory experiments, a larva that happens to fall into another's pit, a fight is set up between the two predaceous creatures. The victim, in trying to escape, leaps for several times in the air but may be unable to avoid falling away from its neighbour's pit. In this case, the other larva gets a good hold of the sand, tries at first to drive it outside the pit but then captures it, paralyzes it, and finally feeds upon it. Even pupae may be eaten by the larvae if they come across them. Also the adults, which during the next hour after emergence are soft-bodied, sluggish and unable to fly, may unfortunately fall in the larval pits and are then devoured by the larvae.

With the exception of this voracious nature of its own species, no other enemies of *Vermileo* were observed.

When the larva neglects the pit, this indicates that it is searching for a more suitable place, about to moult or to pupate.

When the larva is ready to moult, it neglects its pit and conceals itself in the sand. The old skin then comes out in the form of a white flat opaque structure having the shape of the larva but with a longitudinal slit extending from the head to the last abdominal segment. Attached to the exuvium are the sloughed dark brown cephalo-pharyngeal skeleton and also the tracheae. These moult skins are usually thrown by the larvae outside the pit.

As to the duration of the larval stage, it seems that the larva requires quite a long period to transform into adult. This is supported by the fact that the first stage larvae kept under room conditions did not exceed 5 mm. after 18 months. For this reason it was not possible to include in this work the experiments conducted to compare between the duration of the different larval stages. However, Wheeler (1931) stated that *Vermileo comstocki* normally requires two years to complete its life-cycle, and that the larva passes through five instars. This point needs to be tested in the case of *Vermileo vermileo*, and will be carried out in the future.

VII. EXTERNAL MORPHOLOGY AND INTERNAL ANATOMY OF THE LARVA

1. External morphology

The mature larva (Fig. 7) measures from 10 to 12 mm. in length. The general shape of the body is that of a typical maggot. It is elliptical in cross-section, being broader than high. The body segments increase gradually in size from the narrower anterior end to the obliquely truncated posterior end.

The larva is yellowish in colour. The middle region of the body is dark

green due to the contents of the alimentary canal within. The integument is rough and semi-transparent so that a part of the alimentary canal, the two main tracheal trunks together with tracheal branches can be seen through it.

The body of the larva consists of twelve segments characterised by a number of annulations which are well represented in the thorax and the anterior abdominal segments. It is noteworthy that the anterior well annulated part of the body acts as an elaborate shovel for constructing and repairing the pit and also helps in siezing the prey.



Fig. 7 : Mature larva of *Vermileo vermileo*, ventral view, $\times 10$.

The lateral margins of the body carry numerous bristles which are stouter in the three thoracic segments.

The head of the larva is very small and can be easily telescoped within the first thoracic segment. The head contains the dark brown and high'y chitinised head skeleton which extends nearly to the end of the first thoracic segment. The larval eyes are in the form of two minute deeply pigmented bodies situated on the antero-lateral regions of the head capsule.

The three thoracic segments are markedly annulated and not sharply defined from each other. With the exception of the long stiff bristles carried on the side of the thoracic segments and the pair of spiracles carried on the prothorax, no other structures seem to be found on the thorax.

The first abdominal segment carries ventrally, near its anterior border, a small median unpaired protrusible pseudopod (Fig. 8,PD). This is a fleshy extension from the ventral side of the body carrying at its tip four or five flat rigid pointed bristles. The pseudopod of *Vermileo* was first described by De Geer (1752) and Reaumur (1753). Green (1926) mentioned that the larva of *Atherix* (Rhagionidae) has a pair of pseudopods on each of its abdominal segments from the first to the seventh, and a pair of such structures fused except at the tips, carried on the eighth abdominal segment.

The last two abdominal segments (Fig. 9) are turgid and show no annulations. On the dorsal limit between the seventh and eighth segments, there is a comb-like row of about eleven bristles alternating with smaller ones. These bristles are flat with broad bases and pointed tips. According to Engel (1928), these bristles help the larva to anchor into the sand.

The eighth abdominal segment ends in four conical fleshy lobes, the two outer of which are larger than the inner ones. The margins of these lobes are bordered by relatively long bristles.

The head skeleton of the larva (Fig. 10) is an oval dark brown highly chitinised structure which extends nearly to the end of the first thoracic segment and can be easily seen through the integument.

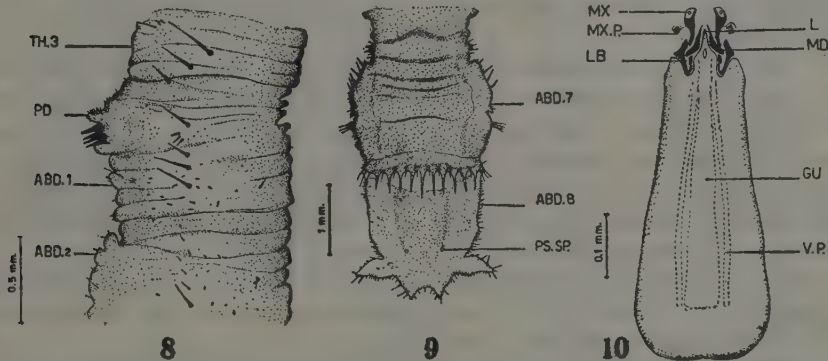


Fig. 8 : First abdominal segment of the larva, lateral view (ABD. 1, first abdominal segment; ABD. 2, second abdominal segment; PD, pseudoleg; TH. 3, last thoracic segment).— Fig. 9: Terminal part of fullgrown larva, dorsal view (ABD. 7, seventh abdominal segment; ABD. 8, eighth abdominal segment; PS.SP., posterior spiracle). — Fig. 10: Head skeleton of fullgrown larva, dorsal view (GU, gula; L, labrum; MD, mandible; MX, maxilla; MX.P, maxillary palp; V.P., ventral process).

The head skeleton varies in size from one larval instar to the other: that of the last stage larva measures from 0.55-0.67 mm. in length, the anterior width varies from 0.13-0.16 mm. and the posterior width from 0.20-0.27 mm. The greater part of the head skeleton forms the head capsule which is slightly curved dorsally and carries the mouth-parts anteriorly. Ventrally, it is provided with a median unpaired flat prolongation termed the gula (Fig. 10, GU) which ends a short distance behind the posterior edge of the head capsule. On either side of the gula and more or less parallel to it there is a pair of rod-like structures called ventral processes (Fig. 10, V.P.).

The mouth-parts consist mainly of a median unpaired labrum and paired mandibles, maxillae and labium. The labrum (L) is a small triangular pointed structure the basal portion of which is less chitinised than the tip. On either side of the labrum is a small mandible (MD) extending beyond the tip of the labrum. The maxillae (M) are well developed, each carrying a small tubular maxillary palp (MX.P.) The labium (LB) is a small chitinised sclerite situated on the sides of the head capsule.

2. Internal anatomy

The alimentary canal

The alimentary canal of the larva (Fig. 11) runs straight from the mouth to the end of the mid-gut and becomes coiled in the region of the hind-gut. It is slightly longer than the body. The mouth opening leads into the pharynx (PX) which is a small narrow tube followed by a short oesophagus (OE). This opens into the crop (CR) which is a small rounded part leading into the mesenteron.

The mid-gut or mesenteron (MES) constitutes the greater part of the alimentary canal and likewise occupies a large space of the body cavity. It is in form of a large blind sac extending from the thorax to the end of the seventh abdominal segment. The mesenteron is always filled with both undigested food and waste products in the form of a thick emulsion. When the mid-gut ruptures, these contents exude in the form of thread-like heavy fluid which is not rapidly miscible with water.

The junction between the mid-gut and the hind-gut remains blocked throughout the larval period and becomes opened only few days before pupation to evacuate the contents of the mid-gut.

The hind-gut (HG) is a long slender coiled tube. Its narrow lumen communicates with the outside by means of the slit-shaped anal opening found on the ventral side of the eighth abdominal segment (Fig. 7).

At the junction of the mid-gut and hind-gut, open four Malpighian tubes (Fig. 11, M.TU.). These are very long, extending in the body cavity and entangled with the other internal structures. Each tube exceeds in length the total length of the alimentary canal.

A great part of the space between the integument and the internal structures is occupied by masses of fat tissue, which are specially accumulated around the Malpighian tubes.

The salivary glands

The salivary glands of the larva (Fig. 12, S.GL.) are well developed long structures of uniform thickness. They extend on either side of the alimentary canal nearly to the end of the sixth abdominal segment. Anteriorly each gland is connected to a small narrow duct. The two ducts of both sides join into a common salivary duct (S.D.) which extends below the head capsule and opens into the mouth.

It seems probable that the salivary glands produce the secretions responsible for paralysing the prey.

The central nervous system

The central nervous system of the larva (Fig. 13) is simple, consisting

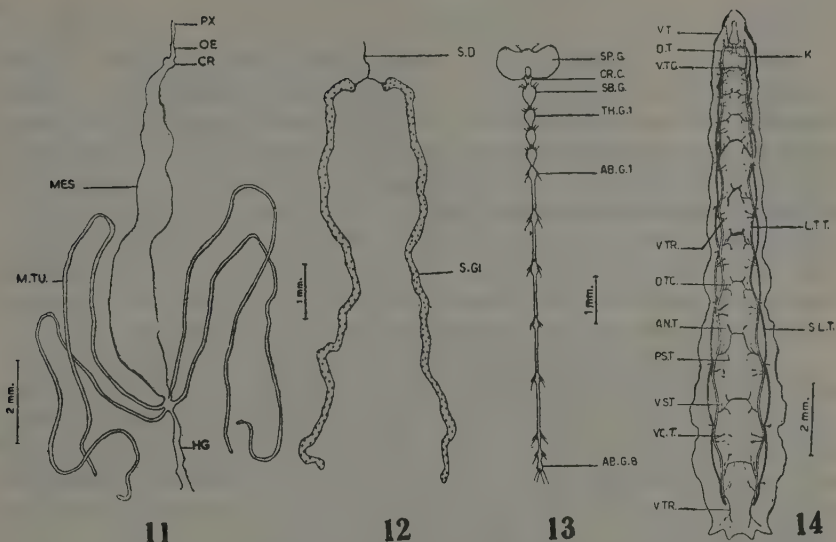


Fig. 11 : Alimentary canal of larva, hind gut stretched (CR, crop; HG, hind gut, M.TU., Malpighian tube; MES, mesenteron; OE, oesophagus; PX, pharynx). — Fig. 12 : Salivary glands of larva (S.D., salivary duct; S.G.L., salivary gland). — Fig. 13 : Central nervous system of larva (AB.G.1 and AB.G. 8, first and eighth abdominal ganglia; CR.C., circum-oesophageal connectives; SB. G., sub-oesophageal ganglion; SP. G., supra-oesophageal ganglion; TH.G.1, first thoracic ganglion). — Fig. 14: Respiratory system of larva (AN.T., anterior trachea; D.T., dorsal cephalic trachea; D.T.C., dorsal transverse commissure; K, network of tracheae; L.T.T., main longitudinal tracheal trunk; PS.T., posterior trachea; S.L.T., secondary longitudinal tracheal trunk; V.T., ventral cephalic trachea; V.T.C., ventral transverse commissure; V.T.R., ventral trachea; V.S.T., vascomuscular branch).

mainly of the brain or supra-oesophageal ganglion, the sub-oesophageal ganglion and the ventral nerve cord.

The supra-oesophageal ganglion (SP.G.) is large and well developed and situated above the oesophagus and behind the head skeleton, and is connected to the sub-oesophageal ganglion (SB.G.) by the circum-oesophageal connectives (CR.C.). According to Wheeler (1931), the position of the brain behind, instead of within the head capsule, is very unusual among insects; however, Bugnion (1922) has shown the same state of displacement in the larvae of the fire-flies (Lampyridae).

The ventral nerve cord carries three thoracic and eight abdominal ganglia, one for each body segment. From the ganglia nerves arise supplying the adjacent organs. The last two abdominal ganglia are closely approximated.

In the comparative absence of fusion between the ganglia, the nervous system is very similar to that of Xylophagidae, Asilidae, and Therevidae (Brauer, 1883), and Pantophthalmidae (Thorpe, 1934).

The respiratory system

The larva is amphipneustic. The anterior pair of spiracles is very minute carried on the prothorax, the posterior pair is placed within a deep depression on the dorsal surface of the last abdominal segment. Two main longitudinal tracheal trunks (Fig. 14, L.T.T.) extend on the dorso-lateral regions of the body and connect the anterior and posterior spiracles. A secondary longitudinal tracheal trunk (S.L.T.) runs along each side of the main trunks throughout its whole length and is connected and communicates with it in each body segment. In this way a series of closed segmental loops are formed along the sides of the body. The main and secondary trunks of each side become connected near the posterior spiracle.

The main longitudinal trunks are connected to each other dorsally in each body segment, from the first thoracic to the last abdominal, by a dorsal transverse commissure (D.T.C.). Each of these commissures gives off anteriorly two vasco-muscular branches (V.S.T.) together with anterior tracheae (AN.T.) and posterior tracheae (PS.T.). The first dorsal transverse commissure gives off on either side a net-work of tracheae (K) and provides the head anteriorly with a pair of dorsal cephalic tracheae (D.T.).

In the region of the thorax there are two ventral transverse commissures the first of which supplies the head with a pair of ventral cephalic tracheae (V.T.). According to Vimmer (1931), the ventral transverse commissures have a phylogenetic significance since they are present in the early stage larvae of the higher Cyclorrhapha and disappear as they moult.

The secondary longitudinal tracheal trunk sends to each body segment, a visceral tracheal branch (VC.T.) and a ventral branch (V.TR.). In the last abdominal segment, the secondary trunk of each side gives one ventral trachea which divides into two branches, thus resulting in four branches on both sides. Each of these branches supplies one of the lobes at the posterior end of the body.

VIII. SUMMARY

The field and laboratory studies on *Vermileo vermileo* larva are summarised in the following. :

The larvae live in conical pits which they construct in the sand in certain valleys (wadies) of the Egyptian Eastern Desert (between Cairo and the Gulf of Suez), beneath the sloping undersurfaces of overhanging limestone cliffs.

Climatic conditions

The climatic conditions prevailing in one of these localities (Wadi Digla)

are as follows :

Rain is scarce, not exceeding few millimetres per year (e.g., in 1953 the total rainfall was 6.9 mm. in 38 days).

Temperature (in shade) is highest in May and June (about 43°C.) and lowest in January (about 4°C.).

Relative humidity reaches its minimum in May, then increases steadily till December and falls again in the spring.

The temperature of the sand in which the larvae construct their pits is lower than shade temperature on relatively hot days, and higher on relatively cold days.

The habits of the larva and larval food

The larval pits are always aggregated in clusters commonly known as colonies. When moving from one place to another, the larva crawls on its back. It leaps in the air when mechanically irritated, feigns death and usually assumes the form of the letter U when sieved from the sand. It digs its pit during the day and repairs it by the approach of night, thus the larvae are negatively phototactic. The diameter of the larval pit varies according to the size of the larva and ranges between a few millimetres and 2.5 cm. The larvae sometimes wander at night and leave long sinuous grooves over the surface of the sand. It was found that the larvae often construct their pits beside solid objects and at the bases of rocks, possibly, for protection from the direct unfavourable effect of sun, rain and wind . Prior to pupation, the larva stops feeding and constructing pits, but in other respects behaves more or less like the feeding larvae. This is the prepupal stage which lasts from 4 to 6 days.

The larvae are predaceous. They capture their prey in the conical pits which they construct in the sand. Their food consists of aphids, ants, small caterpillars and other small soft-bodied insects. The larva can withstand thirst and starvation for long periods varying from 3 to 12 months according to age and size. The larvae are cannibalistic, they feed on each other, also they eat pupae and adults of their own species. The contents of the alimentary canal of the larva are retained throughout the larval life and become evacuated before pupation.

The morphology of the larva

The general shape of the larval body resembles that of a typical maggot. The body carries lateral bristles which are well developed, specially in the thorax. The head is somewhat developed and can be retracted within the body. It contains a well developed head skeleton which carries the mouth parts anteriorly. The first abdominal segment carries a median unpaired

pseudo-leg, which terminates in 4-5 strongly chitinated flattened spines. The abdomen is 8-segmented and ends in 4 conical lobes. The last abdominal segment carries anteriorly a row of flattened bristles.

The mid-gut occupies a large space of the body and forms the greater part of the alimentary canal. The hind-gut is a small coiled tube opening to the outside by the anus. The junction between the mid- and hind-gut remains closed throughout the larval life and becomes opened only few days before pupation.

IX. REFERENCES

- Anonymous (1706) : Histoire de l'Académie Royale des Sciences.
Chapitre : Diverses observations de physique générale, Observation VI, page 7 (*Vermileo*).
- Bezzi, M. (1898) : Contribuzioni alla fauna Ditterologica Italiana : II. Ditteri della marche e degli Abruzzi (*Bull. Soc. Ent. Ital.*, pp. 19-50).
- Brauer, F. (1883) : *Vermileo degeeri* Macq. (*Wien. Ent. Zeitg.*, II, p. 114).
- Buchner, P. (1940) : Ueber den Wurm-lowen (*Vermileo vermileo*) (*Natur. u. Volk*, Frankfurt a.M., LXX, pp. 116-131, 14 figs).
- Bugnion, E. (1922) : Etudes relatives à l'anatomie et à l'embryologie des vers luisants ou Lampyrides (*Bull. Biol. France Belg.*, LVI, pp. 1-53, 36 figs.).
- Buxton, P.A. (1923) : Animal life in deserts (London, Edward Arnold and Co.).
- Courtilier, A. (1867) : *Leptis vermileo* (Fabricius) (*Ann. Soc. Linn. Dépt. Maine-et-Loire*, IX, pp. 72-75, 1 pl.).
- De Geer, C. (1752) : Ron om Mask-Lejonet (*Vetensk. Akad. Handl.*, pp. 180-192, 261-263, 1 pl.).
- Engel, E.O. (1929) : Notes on two larvae of south African Diptera belonging to the families Leptidae and Asilidae (*Trans. Roy. Soc. South Africa* (Cape Town), XVIII, pp. 147-162, 20 figs.).
- Greene, Charles T. (1926) : Descriptions of larvae and pupae of two-winged flies belonging to the family Leptidae (*Proc. U.S. Nat. Mus.*, LXX, art. 2, pp. 1-20, 3 pls.).
- Malloch, J.R. (1917) : A preliminary classification of Diptera exclusive of Pupipara, based upon larval and pupal characters, with keys to imagines in certain families [Part. I] (*Bull. Ill. State lab. Nat. Hist.*, XII, pp. 161-407, 57 pls.).
- Meijere, J.C.H. de (1916) : Beitrage zur Kenntnis der Dipteren-Larven und Puppen (*Zool. Jahrb. Abt. System.*, XL, pp. 177-322, pls. iv-xiv, Jena).
- Pechuman, L.L. (1938) : A synopsis of the world species of *Vermileo* [Rhagionidea] (*Bull. Brooklyn Ent. Soc.*, XXXIII, pp. 84-89).

- Reaumur, R.A.F. de (1753) : Histoire du ver-lion mouche (*Mém. Acad. Sc. Paris*, pp. 402-419, 1 pl. [Ed. 1762, pp. 604-631]).
- Siebold, C.T.E. von (1861) : Ueber die Larve von *Leptis vermileo* (Amtl. Ber. 35 Versam. Deutsch. Naturf. u. Aerzte in Koenigsberg, 1860, pp. 105-107).
- Thorpe, W.H. (1934) : Observations on the structure, biology and systematic position of *Pantophthalmus tabaninus* Thumb. [Dipt. Pantophthalmidae] (*Trans. R. Ent. Soc. London*, LXXXII, pp. 5-22, 20 figs.).
- Vimmer, A. (1931) : Einige Ergänzungen zur Anatomie der Larve von *Vermileo*, nebst Bemerkungen ueber die Mundwerkzeuge der Larven der Fam. Rhagionidae im Allgemeinen (*Acta Soc. Ent. Czech.* (Prague), XXXVIII, pp. 47-53, 2 figs. [in Czech with german summary]).
- Wheeler, W.M. (1931) : Demons of the dust (London, Kegan Paul, Trench, Trubner and Co., xviii + 378 pages, 1 pl., 49 figs.).
- Williams, C.B. (1923) : A short bioclimatic study in the Egyptian desert (Bull. No. 29, Tech. Sci. Serv., Ministry of Agriculture, Cairo, 20 pages, 11 figs.).
- Williams, C.B. (1924) : A third bioclimatic study in the Egyptian desert (Bull. No. 50, Tech. Sci. Service, Ministry of Agriculture, Cairo, 32 pages, 7 figs.).
- Williams, C.B. (1924a) : Bioclimatic observations in the Egyptian desert (Bull. No. 37, Tech. Sci. Serv., Ministry of Agriculture, Cairo, 18 pages, 10 Figs.).
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Biology of the Red Spider Mite, *Eotetranychus cucurbitacearum* Sayed

[Acarina : Tetranychidae]

(with 8 Text-Figures and 7 Tables)

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Introduction. — Material and Methods. — Infestation. — Host plants. — Description. — Life-history. — Mating. — Oviposition. — Hatching. — Moulting. — Web spinning. — Seasonal variations : (a) incubation period, (b) immature stages, (c) pre-oviposition period, (d) duration of generations. — Longevity. — Number of generations. — Sex ratio. — Natural enemies. — Summary. — References.

INTRODUCTION

The red spider mites of the family Tetranychidae are widely distributed all over the world. They are considered major pests to many truck crops, field crops, fruit trees, and ornamental plants.

The most common member of this family is the red spider *Tetranychus telarius* L. It has been recorded as a serious pest all over North and South America, Hawaii Islands, South Africa, Australia, India, Palestine, and in Europe as North as Germany.

In Egypt, the common red spider mite was for a long time wrongly confused with *Tetranychus telarius* L. Sayed (1946) found out that it represented a new species, which he described under the name of *Eotetranychus cucurbitacearum*, and reported it as the most prevalent and the most important mite in the Country. It is a serious pest to many economic plants such as cotton (*Gossypium barbadense*), berseem (*Trifolium alexandrinum*), edible figs (*Ficus carica*), common beans (*Phaseolus vulgaris*), egg-plant (*Solanum melongena*), water-melon (*Citrullus vulgaris*), and other cucurbits. Also, it is a pest of many ornamental plants.

The biology of this mite, despite its damage to many crops, has not been

thoroughly investigated, and therefore a detailed study under Egyptian climatic conditions has been found necessary. This work was carried out in the farm of the Faculty of Agriculture at Giza, from October 1951 to January 1953.

MATERIAL AND METHODS

Various methods of rearing red spiders have been applicated by different investigators, such as McGregor and Donough (1917), Gilliatt (1935), Klein (1936), Cagle (1943 and 1946) and Rahman and Sapra (1945).

The technique adopted in the present work is a modification of that used by Klein (1936). In October 1951, several females of *Eotetranychus cucurbitacearum* Sayed of different stages were collected from cucurbit plants grown in the field of the Faculty of Agriculture (Giza). They were left to deposit eggs on bean leaves. Adults resulting from this generation were left to copulate. Mated females of about the same age were thus available for experimental purposes.

The common bean *Phaseolus vulgaris* was used as the host plant. Plants were grown singly in pots 20 cm. in diameter. Fifteen to twenty-five female mites were then placed on the plants grown under natural climatic conditions. The pots were arranged alternatively at 50 cm. apart on wooden stands. The distance between the stands was also 50 cm. from each other. Ants and other crawling enemies were prevented by putting the supports of the stands in tin cans full of water. The experiments were carried out in a large wire screen cage measuring 4x5 or twenty square metres, and 3 metres in height. To avoid the effect of wind, a strip of canvas about one meter in width was fixed round the cage at the level of the host plants at about 80 cm. from the ground. To avoid rain, the cage was covered by burlap sheets during winter.

The newly mated females were placed on the under surface of the leaves, one female to each leaf. For confining the mite to the leaf, each female was surrounded by a circle, about one inch in diameter, made of a mixture of canada balsam and castor oil. After the deposition of the first five eggs, the female was transferred to another leaf, in a wider circle where it could have more room to continue oviposition. Each female had been transferred more than twice before it deposited all its eggs. In this way eggs could be easily counted. Every newly hatched larva was transferred singly on the point of a pin to another leaf and encircled with the mixture mentioned above. On reaching maturity, the adults were left to mate and to deposit eggs. This technique was followed in rearing all generations. As it will be mentioned later, the number of the males produced was not sufficient to copulate all the

females. Therefore, throughout this work, some of the females were left unmated to produce a number of parthenogenetic males to copulate all the females. Observations were made twice daily, at 8-9.30 and 15.30-17, with the help of a hand lens. A table bearing the necessary records was attached to the infested leaves.

This technique has the following advantages :

(1) Accurate examination was much easier when eggs and mites were confined to a small area surrounded by the canada balsam and castor oil circle.

(2) This circle was much simpler than R a h m a n ' s and ' S a p r a ' s (1945) method, and at the same time the mites were exposed to the natural climatic conditions.

For the study of sex-ratio, each mated female, and no other, was placed on a leaf of a single plant surrounded by a cellophane cone 40 cm. in height. The cone was supported by three wooden sticks attached to the pot. Movement of offspring to or from other plants was thus avoided. Each cone was provided near its top with three openings at different directions to avoid increased humidity and temperature inside the cone. These openings were above the level of the infested leaves on the plants, and so the mites were not affected by the wind. Every emerging adult was killed directly after being counted to avoid miscounting the number of each sex.

To study the effect of direct sunlight on the number of deposited eggs, newly emerged and copulated females were placed separately in the shade on the under surface of the leaves, while others were placed exposed to direct sunlight on the upper surface. Other females were confined, singly, in the shade, to both the upper and lower surfaces of the leaves for comparison. Examination was carried out also twice daily for a period of five days.

INFESTATION

The common red spider mite is characterized by its feeding habits. It feeds on the under surface of the leaves, sucking the sap. Examination of infested plants showed first small white spots which develop on the under surface of the leaf, around each feeding puncture. With the increase of attack, these spots become numerous, gradually coalescing into comparatively large patches which could be seen also from the upper surface. Such infected leaves gradually lose their healthy condition and turn into a rusty brown colour. Finally, the leaves curl, dry up and appear covered by web sheets spun by the mites on the lower surface. Occasionally, these web sheets look dirty and full of dust carried by the wind. This severe infestation decreases the vitality of the plants, affects their growth, blooming, fruiting and finally, the yield.

HOSTS PLANTS

Eotetranychus cucurbitacearum Sayed is a polyphagous mite. It has been collected from the following plants, at Giza.

(1) Vegetables: Beans (*Phaseolus spec.*), cowpea (*Vigna sinensis*), Vegetable marrow (*Cucurbita pepo*), sweet melon (*Cucumis melon*), water-melon (*Citrullus vulgaris*), egg-plant (*Solanum melongena*), globe artichoke (*Syntherisma scolymus*), tomato (*Lycopersicum esculentum*), pepper (*Capsicum frutescens*), lettuce (*Lactuca sativa*), and okra (*Hibiscus esculentum*).

(2) Field crops: cotton (*Gossypium barbadense*), horse beans (*Vicia faba*), and berseem (*Trifolium alexandrinum*).

(3) Ornamental plants: rose (*Rosa spec.*), sweet peas (*Lathyrus odoratus*), violet (*Viola odorata*), carnation (*Dianthus caryophyllus*), nasturtium (*Tropaeolum majus*), sunflower (*Helianthus annuus*), geranium (*Pelargonium spec.*), datura (*Datura arborea*), sage (*Salvia splendens*), amaranthus (*Amaranthus spec.*), and mignonette (*Reseda odorata*).

(4) Weeds: bindweed (*Convolvulus arvensis*), and nettle leaved goose foot (*Chenopodium spec.*).

DESCRIPTION THE OF VARIOUS STAGES

The egg is small and could hardly be seen by the naked eye. It is spherical in shape, measuring about $107\ \mu$ in diameter. When newly laid, it is translucent and whitish in colour, but later it turns to light brown. Before hatching, the carmin eyes of the embryo could be seen through the chorion.

The larva (Fig. 1A), when just hatching, has about the same size and shape of the egg. It is pale reddish, with carmin eyes and three pairs of legs. After feeding, it becomes elongate and turns to light green with two dark spots on the dorsal side behind the eyes, while the legs and the rostrum are semi-transparent. On the average the larva, immediately after hatching, measures $114\ \mu$ in length and $115\ \mu$ in width, but after feeding and before entering the first resting stage, it measures $188\ \mu$ and $152\ \mu$, respectively.

The protonymph differs from the larva by its larger size and the fact that it has four pairs of legs (Fig. 1B). The dorso-lateral dark spots are slightly larger and the bristles are longer. The legs and rostrum are also semi-transparent. It measures $259\ \mu$ in length and $198\ \mu$ in width.

The female deutonymph (Fig. 1C) resembles the protonymph, except that it is larger in size and more elongated. When fully grown, it has about the same size of the adult female. It is green yellowish in colour while its legs and rostrum are semi-transparent. It can be easily distinguished from the male deutonymph which is smaller, elongate and triangular in shape posteriorly (Fig. 1D). By measuring a number of deutonymphs, the average length of the female is $380\ \mu$, while that of the male is $324\ \mu$.

The adults have been described by Sayed (1946).

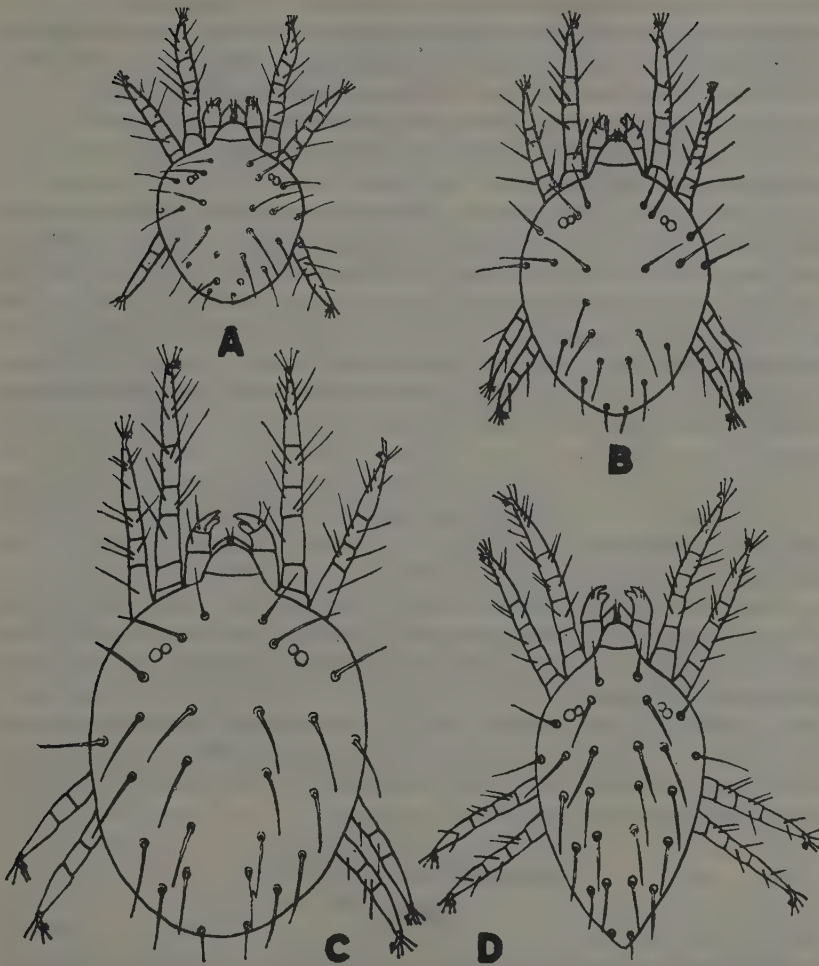


Fig. 1 : Stages of *Eotetranychus cucurbitacearum* Sayed (A, newly hatched larva; B, protonymph; C, deutonymph female; D, deutonymph male).

LIFE-HISTORY

The females deposit their eggs singly on the under side of the leaves. The newly hatched six-legged larvae feed for a short time and then enters the first quiescent stage from which the first eight legged protonymphs emerges.

These nymphs are more active, and when full-grown they go through

the second quiescent stage after which they change to deutonymphs. Finally, the deutonymphs enter the third quiescent stage and then the adults appear.

McGregor and McDonough (1917 and 1950) stated that, in addition to the larval stage, the females before reaching the adult stage required two nymphal stages whereas the males required only one.

These findings are confirmed by Klein (1936), Janjua (1942), and Rahman and Sapra (1945). Cagle (1949), however, observed two nymphal stages for both, females and males of *Tetranychus bimaculatus* Harvey. He also found that, on some occasions, only one nymphal stage was recorded for both sexes. This was more frequent in hot weather, when the development of the mites was so rapid that they went through an active and a quiescent stage in one day. He suggested that such records might have been due to errors in observations. In order to check this finding, he reared 12 individuals hatching from unfertilized eggs and put them under careful observation. In all cases the males passed through the two nymphal stages.

Blair and Groves (1952) also mentioned that males of *Metatetranychus ulmi* Koch, developed from eggs laid by one female, might have either one or two nymphal stages. They added that both cases occurred in the offspring of fertilized and unfertilized females.

In the present investigation, it was found that both males and females passed through two nymphal stages. The parthenogenetic males in all cases (27 generations under observation during one year), showed the same features, which support Cagle's point of view. However, some males which developed from fertilized eggs, passed through one nymphal stage only, but when a female was copulated with a parthenogenetic male, most of the progeny males had two nymphal stages. This phenomenon could only be attributed to heredity.

BIOLOGICAL ASPECT

Mating

Mating takes place after 1-3 hours from the time of emergence of the female and after 12-24 hours from that of the male. This phenomenon explains why the male reaches the adult stage about one day before the female does.

In the mating process, the male shows more activity by running about and rapidly moving its legs. It then approaches the female from behind and crawls under it, while the latter leaning forward on its head, lifts its abdomen and spreads its legs widely apart to give room for the male. The male curves the end of its abdomen both upwards and forwards until it meets the tip of the abdomen of the female. The process of mating lasts 2.5-3 minutes in winter, whereas in summer, it takes only 2 minutes.

Usually, unmated females do not accept any copulation two days after emergence, but in three cases during the course of this investigation the female was observed accepting copulation after depositing the unfertilized eggs, that is after about two days (Cagle, 1943).

During the course of observation, it was noticed that the female copulated once, while the male could copulate 2-4 females within one hour. The male takes a comparatively longer time in the first mating than in the last one. Males usually fight against each other to win one female. Some males are so keen to win the female that they wait for its emergence by staying on the back of or very close to, the quiescent deutonymph (Gilliatt, 1935; Klein, 1936; Janjua, 1942, and Cagle, 1946).

Parthenogenesis is common and only males emerge from unfertilized eggs. These males behave exactly as the sexual males in the process of mating. Parthenogenesis is essential as females usually outnumber sexual males and so the shortage in the latter sex can only overcome through the production of parthenogenetic males (McGregor and McDonough, 1917).

Oviposition

Usually, the female deposits eggs singly on the under surface of the leaves, preferring the spaces between veins. During the oviposition period, it weaves webs among which it usually deposits the eggs. In heavy infestation, the female also deposits eggs on the upper surface of the leaves, twigs and buds.

McGregor and McDonough (1917) found that the number of eggs deposited by the female *Tetranychus bimaculatus* H. varied according to temperature, locality and host plant.

The average number of eggs deposited by the female *Eotetranychus curbitacearum* Sayed during the course of this work is 72 in winter, 88 in spring, 111 in summer and 152 eggs in autumn. The number of eggs varies according to seasons, the maximum being in autumn, while the minimum occurs in winter. The analysis of variance shows that there is non-significant difference between the number of eggs deposited in winter and that deposited in spring, while there is a significant difference between the number deposited in summer and spring and that deposited in summer and autumn. It is obvious that the difference between the means for both autumn and winter is highly significant.

There is also a significant difference between the number of eggs deposited on both day and night in the winter, spring and summer. These differences may be attributed to the variations in temperature. In the autumn, however, a non-significant difference is observed although the temperature variation still exists. This may be due to the comparatively high humidity of the autumn nights.

In an attempt to find out the effect of direct sunlight and shade on the number of eggs deposited, experiments were carried out in July 1952. The results show a significant difference between the number of eggs deposited in direct sunlight and that deposited in the shade, the number being higher in the latter. It is worth mentioning that the females in direct sunlight become restless and some of them died in the canada balsam and castor oil circle due to the effect of the light, heat or evaporation during the day.

No difference is found in the number of eggs deposited by females bred on the upper or lower surfaces of the leaves.

The oviposition period changes from one season to another, being longer in winter than in summer. The averages are 20.5, 11, 12.6 and 20 days in winter, spring, summer and autumn, respectively.

Hatching

The newly deposited eggs are globular in shape, translucent and rather whitish in colour. Before hatching, the colour changes to opaque, then to pale brownish. The carmin eyes appear through the chorion. Then one side of the egg shell becomes whitish. A slit is formed in that side from which the larva crawls out leaving the shell intact on the surface of the leaf.

Moulting

Before moulting, the larva or nymph enters into a resting or quiescent stage. In this stage, it stops feeding and movement, and becomes pale yellowish in colour. The two front pairs of legs extend parallel to each other with the rostrum stretched forwardly, while the hind pairs of legs (the 3rd and 4th) extend backwardly along the sides of the body. The quiescence usually takes place near or beside the vein of the leaf. It was observed that all the other resting stages of one mite always occurred at or near the same position of the first ecdysis.

Immediately before moulting, the skin becomes whitish and glimmering at about the middle of the dorsal surface between the cephalothorax and abdomen. A circular rupture of the skin appears around the body at this position. The mite then tries to disengage its fore-legs and anterior portion of the body by twisting and wrinkling movements of the rostrum and fore-legs. After that, it crawls forward trying to get rid of the posterior part of the exuvia. It was noticed that the skin was completely ruptured around the body. *McGregor* and *McDonough* (1917) observed, however, that the rupture of the old skin occurred only at the dorsal surface, and so the exuvia was not completely split around the body.

During the course of the present investigation, it was observed that the males approached the resting female deutonymphs and climbed over their backs and waited to help them to get rid of their exuviae.

Spinning webs

Spider mites receive their name from their ability to spin webs over plant leaves. Earlier workers contend that threads issue from the anal end of the body. Ewing (1914) asserted that the silk emerged near the anus and that the tarsal claws and the tenent hairs were used in its manipulation. Blaauvelt (1945) stated that silk glands are located over coxa I and II,

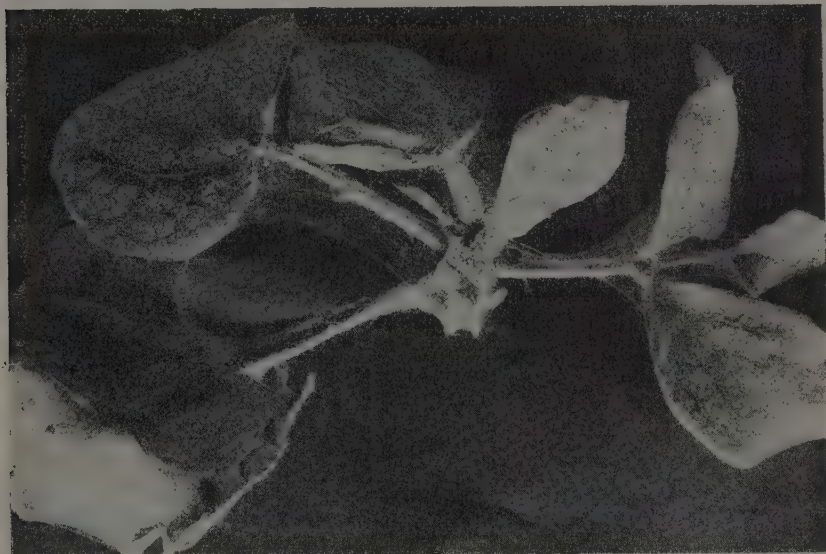


Fig. 2 : Spun webs on common beans (*Phaseolus vulgaris*) leaves.

the ducts extend along the front of the body where they unite into a common duct which runs anterior ventrad to a point under the tip of the rostrum. Baker and Wharton (1951) cited that Grandjean (1948) believed that silk glands were located in the palps opening on the palpal thumb through the broad rounded terminal finger.

The females of *Eotetranychus cucurbitacearum* Sayed prefer concave areas, generally between two veins where they spin their webs. A number of these patches are usually so close to each other that they form a single sheet of webs covering the lower surface of the leaf. The fine threads extend normally from one point to another on one leaf or between leaves or twigs (Fig. 2). These threads serve as a means for the female mites to move from one place to another.

The webs are normally confined to the under surface of the leaves, but

in heavy infestations they may occur on all parts of the host plant. In such cases, all apical portions of the plant have webbing appearance.

Seasonal variations

It is known that temperature, humidity and wind are the main factors affecting the activity and abundance of insects in the field. In the present work, the wind was artificially excluded by canvas sheets around the breeding cage. So the effect of temperature and humidity on the biology of this mite were the main object of study in this investigation.

Incubation period

The temperature seems to be the most important factor affecting the incubation period of *Eotetranychus cucurbitacearum* Sayed. From Table I, it could be seen that a highly significant negative correlation exists between the incubation period and the average temperature.

TABLE I

	SIMPLE (R) ACTUAL FIGURES	PARTIAL (R) ACTUAL FIGURES	SIMPLE (R) LOGARITHMIC
Correlation coefficient	-0.872	-0.835	-0.974
Level of significance	<0.001	<0.001	<0.001

It is found that by plotting the incubation periods of 1600 eggs against the average temperature on a semi-logarithmic paper, the points fall approximately along a straight line (Fig. 3) indicating that the exponential equation $W = Ae^{bx}$ (Snedecor, 1948) would express such a relation. In this equation W = the incubation period in days; x = the average temperature in °C.; and A and b = constants.

By substituting the values of constants in the general equation it is found that $-0.0976 \times W = 50.23$ (2.7182)

In other words, this equation expresses the relation between the incubation period and the average temperature and can be used in calculating this period at any average temperature. English and Turnipseed (1941), and Cagle (1943) used the same formula and got similar results.

The incubation period ranges from about 21.5 days at an average temperature of 12.3 C° to 3 days at an average temperature of 28.1 C°.

The average length of these periods forms a U-shaped curve as the seasons proceed from January to December. Hatching of the larvae occur after about 21.5 days in winter, 5.5 in spring, 3.5 in summer, and 6 in autumn.

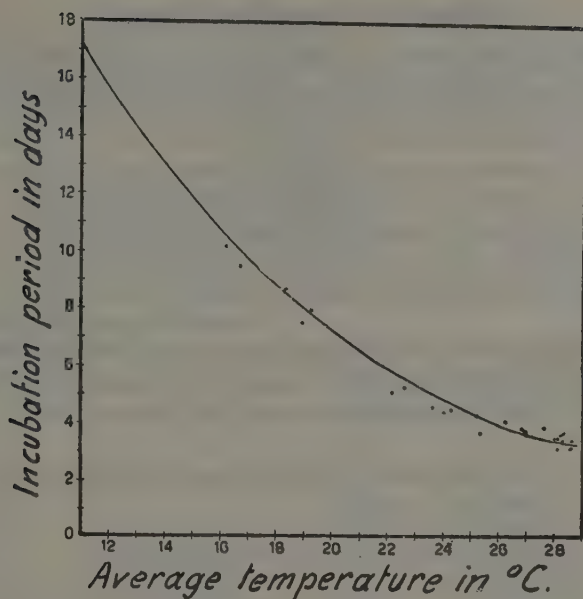


Fig. 3 : Relationship between incubation period and average temperature.

It may be mentioned here that in the case of eggs deposited in direct sunlight on the upper surface of the leaves, the incubation period lasts one day longer than in the case of those deposited in the shade.

Humidity is found to have a comparatively small effect on the incubation period as compared with that of temperature. As shown in Table II, it has a positive significant correlation.

TABLE II

	SIMPLE (R) ACTUAL FIGURES	PARTIAL (R) ACTUAL FIGURES
Correlation coefficient	0.5701	0.387
Level of significance	0.01-0.001	0.050

This statement is supported by the following observations: In some broods the average humidity is almost similar, and yet the incubation periods vary according to the average temperature. In some other cases, considerable variations occur in the humidity while both temperature and incubation periods remain rather constant.

Duration of immature stages

There is a highly significant negative correlation between the temperature and the mean duration of the immature stages as given in Table III.

TABLE III

	SIMPLE (R) ACTUAL FIGURES	PARTIAL (R) ACTUAL FIGURES	SIMPLE (R) LOGARITHMIC
Correlation coefficient	—0.900	—0.905	—0.9504
Level of significance	<0.001	<0.001	<0.001

Figure 4 graphically shows the obvious negative relation between temperature and periods of immature stages. It represents the exponential equation of $-0.0831 \times W = 43.09e$.

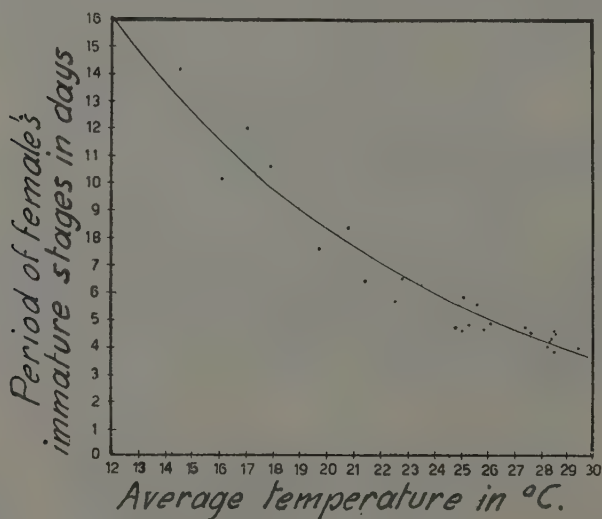


Fig. 4 : Relationship between immature stages and average temperature.

Since there are active and quiescent immature stages, the duration of these stages have to be recorded. The average length of the different stages in both sexes range from summer to winter as follows.

The larval period from 0.7 to 4.4 days, the first resting stage from 0.6 to 2.9 days, the protonymphal stage from 0.6 to 2.3 days, the second resting stage from 0.5 to 2.5 days, the deutonymphal stage from 0.7 to 2.8 days, and

the third resting stage from 0.6 to 3.2 days. Adding the previous periods together, it is found that the length of immature stages shows variation from one season to another. The average total period in January is 19.4 days for the female and 17.2 days for the male, while in July it is 4.3 and 3.6 days, respectively. Thus, the sexes show an obvious difference in the length of their immature stages. This difference is statistically significant as the calculated (*t*) in this case is 7.843 which, with 26 degrees of freedom, is highly significant at less than 0.001 of probability. This agrees with Rahman and Sapr'a's observations (1940 and 1945).

The duration of the immature stages forms a U-shaped curve as months proceed from January to December.

Humidity has a comparatively small effect on periods of immature stages as compared with that of temperature. The calculated correlations between the length of these periods and humidity are shown in Table IV.

TABLE IV

	SIMPLE (R) ACTUAL FIGURES	PARTIAL (R) ACTUAL FIGURES
Correlation coefficient	0.491	0.525
Level of significance	0.02-0.01	<0.001

Pre-oviposition period

Usually, a period elapses between the emergence of the adult female and oviposition. The females are fertilized as they emerge; hence, the pre-copulation period could be neglected. It is found that the pre-oviposition period is highly affected by temperature. In the case of 466 females during the course of a whole year, this period varied from about 0.5-3.5 days as temperature varied from 29.1-13.2°C., respectively.

Generation period

The previous results clearly show that temperature has an important effect on the length of the generation period. This can be seen in Table V.

TABLE V

	SIMPLE (R) ACTUAL FIGURES	PARTIAL (R) ACTUAL FIGURES	SIMPLE (R) LOGARITHMIC
Correlation coefficient	-0.917	-0.927	-0.979
Level of significance	<0.001	<0.001	<0.001

A study of the length of the life-cycle and of the average temperature disclose that the data approximate a straight line when plotted on a semi-

logarithmic paper (Fig. 5). The equation derived from this data is $W = 107.5 (e)^{-0.0922 \times}$

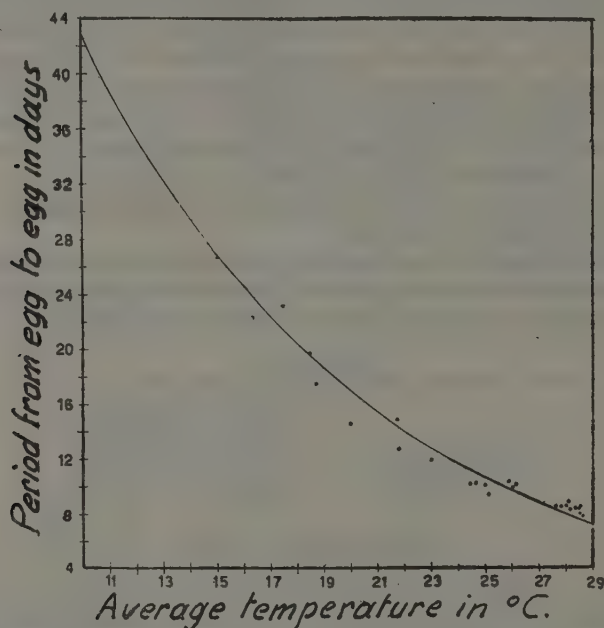


Fig. 5 : Relation between generation period and average temperature.

A maximum of 43.3 days is required for one generation in winter. The corresponding period during the summer is 8.5 days. The shortest periods occur during July and August. So generations form a U-shaped curve as seasons proceed from January to December (Fig. 6).

Generally, humidity shows again its comparatively small effect on the generation period. The correlation values in this case are given in Table VI.

TABLE VI

	SIMPLE (R) ACTUAL FIGURES	PARTIAL (R) ACTUAL FIGURES
Correlation coefficient	0.494	0.652
Level of significance	0.02-0.01	<0.001

Figure 7 shows that the temperature curve varies in almost exactly the opposite direction to the curve of the generation period whereas the humidity

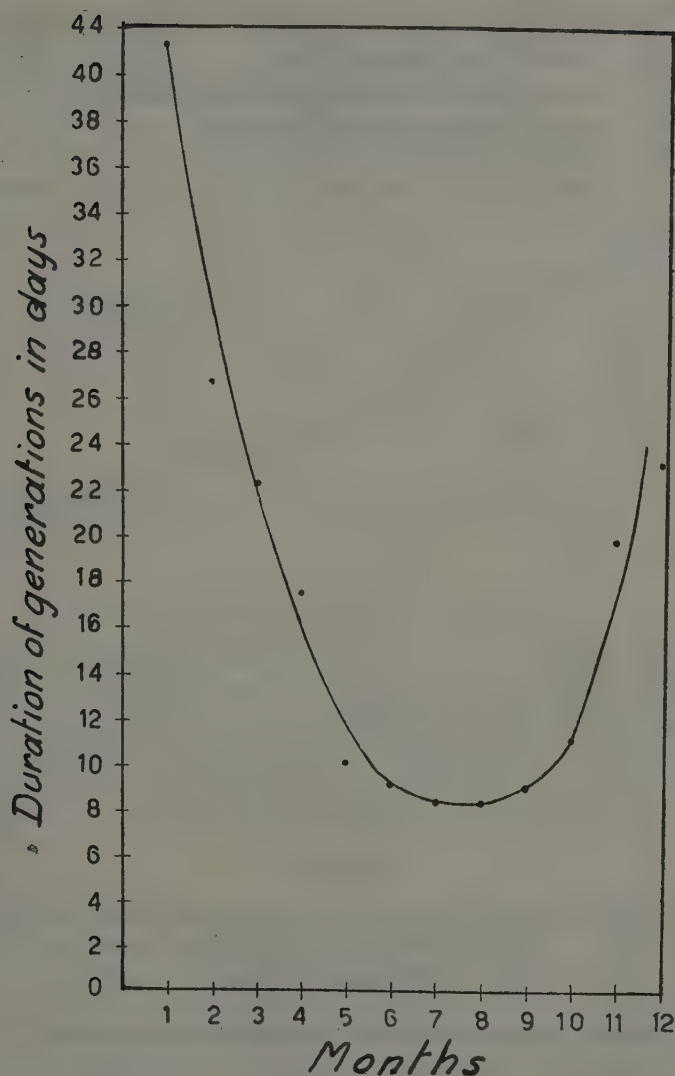


Fig. 6 : Relation between season and length of generation period.

curve does not show such positive constancy. This indicates that the temperature is the main factor affecting the generation periods.

Roberti (1946), in Italy, and Oswald (1949), in Germany, working on *Tetranychus telarius* L., and Oldham (1948), in the United

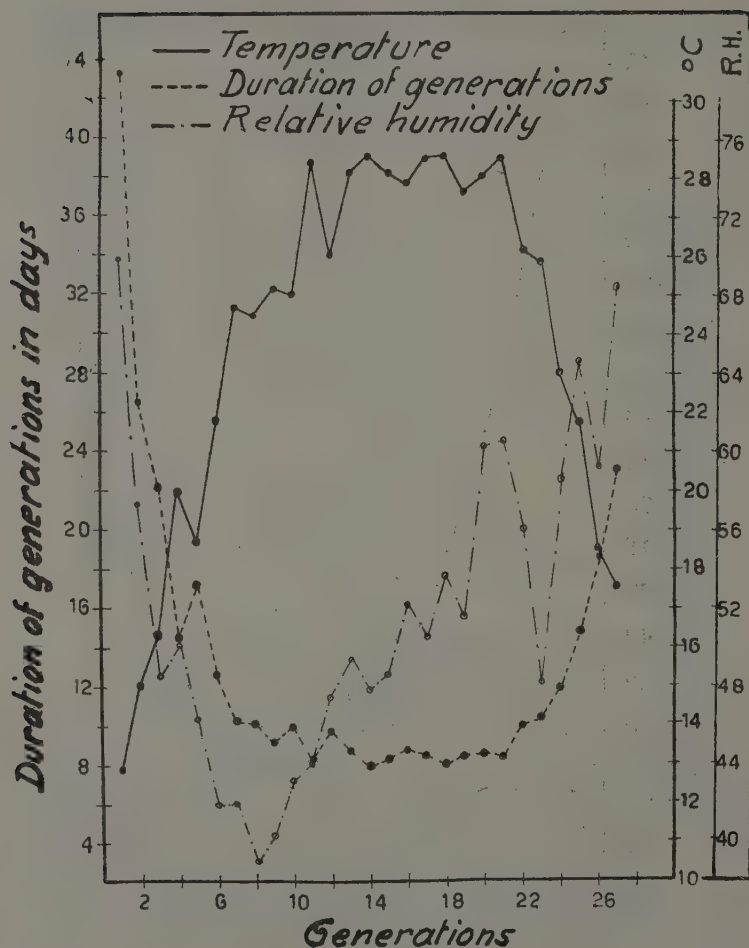


Fig. 7 : Relation between temperature, humidity and generation period.

States, dealing with *Tetranychus sexmaculatus*, all agreed that dry and hot seasons favoured development of these mites.

Number of generations

The life-cycle of the mite varies greatly from one season to another. The periods differ from about 8 days in summer to 43.3 days in winter. Nineteen

generations are completed from May to October. This means that about 70% of the generations occur during the six hot months of the year, whereas the rest takes place during the other six months.

The oviposition period varies according to seasons, and hence, the generations overlap. To avoid the complexity resulting from this fact, the following method was undertaken to find out the approximate number of generations throughout a whole year. Copulated females after being left to deposit

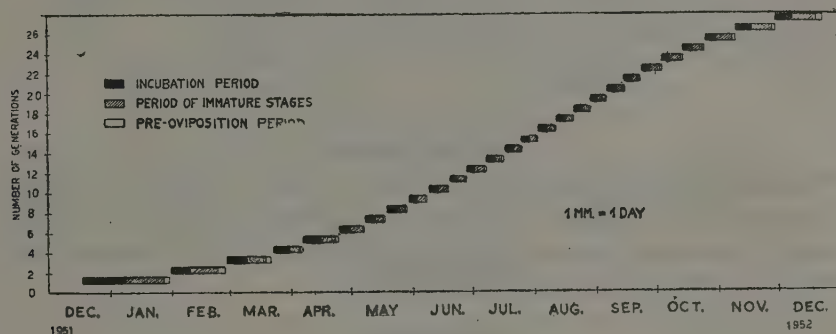


Fig. 8 : Number of generations per year.

their first five eggs, were transferred to other leaves. The five eggs of each female were left to hatch and then each larva was transferred separately to a new leaf and kept under observation till maturity and oviposition. By this way the generation periods could be determined. The results showed that during one year (from December 17th, 1951, to December 20th, 1952) 27 generations of *Eotetranychus cucurbitacearum* could be reared (Fig. 8).

Longevity

The longevity of adults differs according to seasons. Experiments were carried out on some females during the seasons of 1952. Females live for 19-33, 10-16, 10-18 and 12-33 days during winter, spring, summer and autumn, respectively, with one average of 23, 13-13 and 21 days. Rahman and Sapra (1945) noticed that males usually died within 24 hours after copulation. The results in the present work, however, show that copulation has no effect on the longevity of males.

Sex-ratio

It is found that fertilized females give rise to a progeny about 80% of which are females (Cagle 1943, and Rahman and Sapra 1945).

Unmated females deposit eggs which give rise to parthenogenetic males only, while mated females deposit eggs which produce both males and females. Table VII shows that the sex-ratio varies slightly according to seasons.

TABLE VII

SEASONS	NUMBER OF MALES	NUMBER OF FEMALES	PERCENTAGE
Winter	38	145	20.9
Spring	78	225	25.4
Summer	126	538	19.0
Autumn	152	630	18.7

Natural Enemies

During this work, two different predators were observed. These are *Scolothrips longicornis* Priesner (Thysanoptera) and *Orius laevigatus* Fieb. (Hemiptera). The former one was observed by Polizu (1934) who stated that the larvae destroyed many eggs of the red spider.

SUMMARY

The life-history of the common red spider mite *Eotetranychus cucurbitacearum* Sayed was studied under the natural climatic conditions. The mites were reared on common beans (*Phaseolus vulgaris*) as host plants. A certain technique was employed for confining the mites on small spaces on leaf surfaces. The habits of the mite, including hatching, moulting, mating, oviposition and formation of webs, were studied. Experimental studies indicated the following results :

- (1) Twenty seven generations were reared in one year.
- (2) Females and parthenogenetic males have always one larval and two nymphal stages before reaching maturity, but males which developed from fertilized eggs have one larval and many have one or two nymphal stages.
- (3) The incubation period ranges from about 3 days in summer to 21.6 days in winter.
- (4) In summer, the hatching of eggs exposed to direct sunlight is delayed one day as compared to those kept in the shade.
- (5) The larval period ranges from 0.7 to 4.6 days according to seasons, protonymphal period from 0.6 to 2.3 days, and deutonymphal period from 0.7 to 2.9 days.
- (6) The average minimum period from hatching to the adult stage is 3.4 days for males and 3.9 days for females. The maximum period is 17.2 and 19.4 days, respectively.

(7) The pre-oviposition period varies according to seasons, ranging from 12 to 84 hours.

(8) The duration of generations ranges from 7.9 to 43.3 days.

(9) A highly significant negative correlation exists between temperature and incubation period, immature stages, pre-oviposition period, and generations. A comparatively smaller positive correlation also exists between these periods and the relative humidity.

(10) The male emerges about 0.5-2.5 days before the female. There is a significant difference between the duration of generation in both sexes.

(11) The percentage of males reared from fertilized eggs ranges between 18.7 to 25.4%.

(12) The average number of deposited eggs ranges from 79.2 to 151.4 eggs, the maximum number being in autumn.

(13) The natural enemies *Scolothrips longicornis* Preis. and *Orius laevigatus* Fieb., are found to be of considerable importance against the mite.

REFERENCES

- Baker, E.W., and Wharton, C.W. (1952) : An Introduction to Acarology (First printing, The McMillan Company, New-York).
- Blair, A. C., and Groves, J.R. (1952) : Biology of the fruit tree red spider mite *Metatetranychus ulmi* Koch in South East England (*Jour. Hort. Sci.*, XXVII, No. 1).
- Blaauvelt, W.E. (1945) : The internal morphology of the common red spider mite *Tetranychus telarius* Linn. (*Mem. Cornell Agric. Exp. Sta.*, No. 270).
- Cagle, L.R. (1943) : Life-history of the spider mite *Tetranychus schoenei* McG. (*Tech. Bull. Va. Agric. Exp. Sta.*, No. 87).
- Cagle, L.R. (1946) : Life-history of the European red mite (*Tech. Bull. Va. Agric. Exp. Sta.*, No. 98).
- Cagle, L.R. (1949) : Life-history of the two-spotted spider mite (*Tech. Bull. Va. Agric. Exp. Sta.*, No. 113).
- English, L.L., and Turnipseed, G.F. (1941) : The influence of temperature and season on the citrus red mite *Paratetranychus citri* (J. Agric. Rs., LXII, No. 2, pp. 65-77, Washington).
- Ewing, H.E. (1914) : The common red spider or spider mite (*Ore. Agric. Col. Exp. Sta. Bull.*, 121, pp. 29-39, illust.).
- Gilliatt, F.C. : The European red mite *Paratetranychus pilosus* C. and F. in Nova Scotia (*Canad. J. Res.*, XIII (D)).
- Janjua, N.A. (1942) : The biology of the red spider mite *Tetranychus telarius* L. in Baluchistan (*Proc. Indian Acad. Sci.*, XV (B5), pp. 75-77).
- Klein, H.Z. (1936) : Contributions to the knowledge of red spiders in

- Palestine (*Bull. Agric. Res. Sta. Rehavoth*, XXI, pp. 1-63).
- McGregor, E.A. (1950) : Mites of the Family Tetranychidae (*Amer. Midland Nat.*, XLIX (2), pp. 257-420).
- McGregor, E.A., and McDonough, F.L. (1917) : The red spider on cotton (*Bull. U.S. Dept. Agric.*, No. 416).
- Oldham, H.T., and Thorive, F.T. (1947) : Six-spotted mite on Avocado (*Journ. Econ. Ent.*, XL, No. 2, 279 pages, Menasha, Wisc.).
- Osvald, V. (1948) : Rozsireni prifoznych nepratel svilusky chmelovéa vyznam [The distribution of natural enemies of the hop red spider and their importance] (*Ochr. Rost.*, XIX-XX, pp. 99-104).
- Polizu, Non 30 C. (1934) : Supplementary data on Vine Mite (*Bull. Agric. Bessarabia*, Nos. 10-12, pp. 8-9, Chisau).
- Rahman, K. A., and Saprà, A.N. (1945) : Biology of the vegetable red mite *Tetranychus cucurbitae* R. and S. [Family Tetranychidae] (*Indian Jour. Agric. Sci.*, XV, part 3, pp. 124-130).
- Roberti, D. (1946) : A serious attack of red spider *Tetranychus telarius* on citrus along the Sorrento Coast (*Int. Bull. Plant. Port.*, XX, Nos. 3-4, 26 M.-28 M, Rome).
- Snedecov, G.W. (1948) : Statistical methods (Iowa State College Press, Fourth Edition).
- Sayed, M.T. (1946) : Contribution to the knowledge of Acarina in Egypt. Five new species of Tetranychidae (*Bull. Soc. Fouad Ier Ent.*, XXX, p. 78-97).
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Polyhedrosis-virus disease on cotton leaf-worm, *Prodenia litura* F.

(with 6 Text-Figures)

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CONTENTS

I. Introduction. — II. Historical notes. — III. Method and technique. — IV. Symptoms of the disease. — V. The virulence of the disease under different temperature and humidity. — VI. The virulence of the disease on different instars. — VII. The virulence of the disease under natural conditions. — VIII. The infectivity of a non-indigenous polyhedrosis-virus disease. — IX. Histolysis of host tissues due to polyhedrosis. — X. Summary. — XI. References.

I. INTRODUCTION

It is a common practice for those who try to rear *Prodenia litura* in the laboratory to face the problem of keeping the stock of larvae in a healthy condition. In most cases the spread of diseases affects the bred larvae so much that in a few days hundreds or them succumb to the effect of the affliction that may succeed to exterminate the whole lot of the stock. The spread of the fatal disease is greatly helped by the crowding condition in the breeding cage.

This experience met with in the laboratory, combined with field observations, has led several entomologists in the past to realize that such an affliction among the cotton leaf-worms must be due to the spread of infectious agents. The nature of these diseases, as in the case of other insect diseases, was not determined until the science of insect pathology had developed and was able to disclose the exact micro-organism responsible for each case of affliction. The infectious agents responsible for diseases in insects belong to the same major groups as those that cause diseases in other animals : bacteria, fungi, viruses, protozoa and nematodes (Steinhilber, 1949).

The nature of the micro-organism that is responsible for the affliction of the cotton leaf-worm in Egypt was not known until the author had a chance to study some aspects of insect diseases at the Insect Pathology Laboratory

of the University of California. After his return to Egypt, the writer, provided with a better understanding of insect diseases, started collecting and breeding *Prodenia litura* larvae, making observations on the disease symptoms, its incubation period during different seasons, its virulence on the different instars, and following the disease procedure inside the host tissues through microscopical examination of blood smears and thin cross-sections. All results of the study refer to the disease as caused by a polyhedral-virus disease, in which case the virus particles congregate inside certain polyhedral bodies that are formed within the nuclei of the inflicted cells.

The present study is meant to represent and disclose the nature of the disease. As for the possibility of using such affliction as a means of biological control against the cotton leaf-worms, this needs more extended work to clarify factors that are responsible for the non-stability of the virulence of the disease and to gather more information that concerns the behavior of the disease in the field under natural conditions. Attention should be drawn to the fact that in spite of discovering more than a hundred polyhedral-virus diseases affecting different species of caterpillars, yet only in a few cases has it become possible to use the affliction as a practical and economical means of biological control, and this took place after deep and thorough investigation, as in the case of using the polyhedral-virus disease in California against the alfalfa caterpillars, *Colias philodice eurytheme* (Steinhaus, 1948; Steinhaus and Thompson, 1949).

II. HISTORICAL NOTES

Dr. Walter Innes Bey of the School of Medicine in 1888, tried to control the cotton worm by the use of the flacherie disease (*Streptococcus pastorianus*) of the silk-worm (Gantès, 1910). The result seemed encouraging under laboratory conditions, but when applied in the field it had quite a negligible effect.

In 1913, Gerald Dudgeon, Director of the Department of Agriculture in Egypt, in collaboration with Dr. Lewis H. Gough, Chief Entomologist of the Department, tried to infect the larvae of *Prodenia litura* with several types of diseases known to attack lepidopterous larvae, especially the silk-worm, in different parts of the world. According to Dudgeon, the protozoan disease (*Microsporidium polyedricum*) proved to be of such virulence that it pervaded the whole experimental area. This author proposed the use of such a disease as a means of controlling the ravages of leaf eating caterpillars.

Metchnikov, the late eminent insect pathologist of the Institut Pasteur in Paris, when he visited Egypt in 1932, also tried the use of several bacterial diseases against the cotton boll-worm and the cotton leaf-worm.

Willcocks and Said Bahgat (1937) have described the symptoms of a definite virus disease, of which they did not know the causative agent at that time, and which was attacking the cotton worm in breeding cages. Under the same observations Willcocks has added that Mr. A. Alfieri, Secretary General of the Entomological Society of Egypt, has told him that in some places the disease-rotted bodies of *Prodenia* larvae were so very numerous that the air was polluted, the stench being nauseating and overpowering a considerable distance away from the cotton field in which the epidemic was raging.

III. METHOD AND TECHNIQUE

Prodenia larvae, collected from berseem (Egyptian clover) or bred from egg-masses laid on cotton leaves, were reared either "en gros" by keeping large numbers of larvae in breeding cages or singly in carton cylinders provided with bouquets of berseem sprigs and covered with petri dishes. The carton cylinders, the glass tubes containing water and holding the bouquets and the petri dishes were sterilized under pressed steam before use (Steinhäus, 1953). It has been estimated that one milliliter of blood from a polyhedral infected silk-worm contains between 500 and 600 millions polyhedral bodies (Steinhäus, 1949). This count of polyhedra was also taken, in case of *Prodenia litura* disease, as the base for diluting the original material of disintegrated infected larvae with distilled water to form polyhedral suspensions of different concentrations.

Prodenia larvae were infected by offering them berseem bouquets that were contaminated by dipping them in the polyhedral suspension. The suspension used contained from 5 to 10 millions of polyhedral bodies in each milliliter, except in some cases where more concentrated suspensions, that contained up to 100 millions of polyhedral bodies, were used.

Fresh smears of the liquified contents of the inflicted larvae could be examined under the microscope. For more detailed examination the smears were treated with saturated solution of picric acid and then stained with iron haematoxylin. Histological studies of the pathogen were carried out in thin cross-sections of 6-8 μ thick that were triply stained with picric acid, iron haematoxylin and differentiated with eosin (Abul-Nasr, 1954).

IV. SYMPTOMS OF THE DISEASE

The first symptom shown on an inflicted grown larva is that it becomes slack and its body soft or flabby when felt between the fingers. It gradually loses much of its appetite so that it hardly touches the food. The faeces becomes softer instead of being the hard pellets of the healthy larvae. A day before the inflicted larva dies the crochets on the prolegs start to clutch and

stick to the surface. A dark brown fluid oozes out of the anal opening.

On the day before death the larva, particularly the fully grown one, attains a pinkish tint on its ventral surface, compared with the gray-green tint of the healthy larva. This change of colour proved, in many cases, to be quite a pre-mortal symptom. Dead or dying larvae become very soft and flaccid and, when resting on vertical surfaces such as the wall of a cage or container, hang by the four prolegs found on the middle region of the larva, while the fore and hind part of the larva are fallen down (Fig. 1). In case the larva dies while on foliage it usually fixes its hind part by the last two or three prolegs, while the rest of the body hangs freely and becomes swollen with the liquified contents of the disintegrated tissues (Figs. 2 and 3). When recently dead, the inficted larvae are mostly light brown in colour, but other shades are also observed. The very delicate skin is ruptured by any slight disturbance or merely under the weight of the hanging part of the dead larva. The inside contents of recently dead larvae do not have any nasty stench. If the dead larvae are left in open spaces for a few days they soon dry up and become black shapeless masses, but if they are kept in closed spaces, such as small containers or stoppered tubes, the inficted dead bodies become dark brown in colour and acquire a very nauseating stench due to an overpowering culture of putrefying bacteria.



1 2 3
Fig. 1 : Dead body of a virus-infected *Prodenia litura* larva, hung on the wall of container.—Fig. 2: Dead body of a virus-infected *Prodenia litura* larva, hung on a berseem sprig. — Fig. 3: Dead body of a virus-infected *Prodenia litura* larva, hung on a cotton leaf.

Sometimes, larvae that were contaminated with the pathogen and were bred under a continuous coolness at a room temperature of 13 to 16°C., during winter time, showed mixed symptoms. Under such temperature some larvae lived for a period of 12 to 15 days after being infected and when they died their bodies had shrunk and become dark in colour, their inside contents did not liquify and their cuticle kept intact. When smears from such dying or recently dead larvae were examined under the oil immersion lens, polyhedral bodies as well as saprophytic bacteria were both present. In most of these cases the culture of the saprophytic bacteria overpowered that of the polyhedral bodies. The explanation for such phenomenon, of which the author can think, as a reason for the presence of two pathogens at the time of death and for the symptoms not being characteristic for polyhedrosis, is that the continuous cool temperature does not suit the development of the polyhedral virus inside the cells of tissues, and its reproduction proceeds very slowly. The slow attack of the virus is not severe enough to bring mortality to the inflicted larva. Nevertheless, the infliction, slow as it is, causes histolysis to the mid-gut epithelium, fat cells, hypodermal epithelium, and eventually the disintegrated cells are attacked by the saprophytic bacteria, originally found in the digestive tract. At the end, the culture of the saprophytic bacteria becomes so vigorous that it overcomes the original pathogen and starts to attack the rest of the weakened tissues to finish the job that the polyhedral virus failed to accomplish in a suitable length of time.

V. THE VIRULENCE OF THE DISEASE UNDER DIFFERENT TEMPERATURE AND HUMIDITY

The pathogen was tried on definite instars of *Prodenia* larvae at different times of the year at room temperature that ranged between 13 and 16°C. during winter time and between 28 and 33°C. during summer time. The vigour of the pathogen fits with the speed of development of the host; under the optimum temperature of 28 to 32°C. *Prodenia* larvae grow very quickly and so does the virus pathogen in the body of the inflicted larvae, and under low temperature the larvae grow very slowly and the pathogen reproduces also very slowly so that, in many cases, it is hardly able, single handed, to bring death to its host.

In summer time, some of the fully grown *Prodenia* larvae succumbed to the effect of the pathogen on the third day after consuming contaminated food. But most of the larvae died after 4 to 5 days from receiving the pathogen with their food under a temperature that ranged between 28 and 32°C. The more the temperature gets cooler the longer the pathogen takes to bring death to its host. The longest incubation period of the disease was in winter time under a temperature that ranged between 13 and 16°C., when the patho-

gen took 10 to 12 days to show full symptoms on the dead larvae. Other larvae that took a longer time to succumb did not show full symptoms of polyhedrosis.

As for the effect of humidity on the pathogen virulence, observations have proved that increase of relative humidity combined with rise of temperature brings the virulence of the disease to its full measure. Relative humidity that prevails in summer time in Egypt ranges between 60 and 70%. In all cases that humidity was raised due to bad aeration inside the breeding cage, crowding of caterpillars, evaporation caused by water spilled from the glass tubes that hold the bouquets, or by the intended addition of wet sawdust, mortality among *Prodenia litura* larvae was much raised and the incubation period of the disease becomes shorter.

Hundreds of *Prodenia litura* larvae that were collected from breeseem fields during May were kept in several spacious breeding cages that contained a 2 cms. layer of damp sawdust on their floor. In a matter of two days they were sick or dying due to the spread of a polyhedral virus infection. Other larvae were kept singly in corked vials, and to the astonishment of the author some of these larvae manifested full symptoms of polyhedrosis a few hours after their enclosure inside the vials. Naturally it is evident that the latter larvae should have caught the infection previously. Nevertheless, it is quite suggestive that excess of humidity has a bad effect on the physiological state of the tissues of *Prodenia litura* larvae. Association of oxygen shortage with excess of humidity causes the host tissues to be most liable to the quick reproduction of polyhedral virus.

VI. THE VIRULENCE OF THE DISEASE ON DIFFERENT INSTARS

According to the work of Thompson and Steinhäus (1950), on *Colias* polyhedrosis, the result of their test indicates that even the greatest dilution of virus used, 1,000,000 polyhedra per milliliter, is sufficient to give "complete" infection of a field population of *Colias* larvae when applied at a rate of five gallons per acre. These authors determined the effect of the polyhedral-virus infection on the fully grown *Colias* larvae, depending on catches of larvae by net sweeps. The same authors also found that increased concentration may be desirable in cold weather, but is of little, if any, advantage during warm weather.

The virulence of the polyhedral-virus infection was tried on different instars of *Prodenia litura* larvae under the same conditions of temperature and humidity. This took place at two different times : the end of November at 16 to 20°C. room temperature and the beginning of May at 23 to 28°C. A suspension that contained 5 to 10 millions polyhedral bodies per milliliter

was used to contaminate the food. Such concentration of the pathogen did not seem to cause any apparent infection among the first instar larvae. Very few of these larvae succumbed to the effect of the disease, and death took place during the second or third instar of such larvae.

Other concentrations were used and the results obtained referred to the idea that there is a good relation between the concentration of the pathogen and its virulence on the first instar larvae of *Prodenia litura*. The infectivity of the disease was not established before the use of a suspension that contained 50 millions polyhedral bodies. Such concentration of the pathogen killed about half of the infected first instar larvae within 4 to 7 days, depending on temperature, when such larvae were actually on their second or third instar. A more concentrated suspension that contained 100 millions or more polyhedral bodies per milliliter caused 70 to 80% of the infected larvae to succumb. Under warmer temperature (30 to 32°C.), a few of the infected first instar larvae died within 3 to 4 days, before casting their first skin but, in this case, it was very hard relating their death to mere polyhedrosis.

The relation between the pathogen concentration and its virulence was also shown on the second instar larvae of *Prodenia litura*. The apparent infectivity of the disease was not possible before the use of a suspension that contained 25 to 50 millions polyhedral bodies. Most of these larvae succumbed to the effect of the infection within 4 to 7 days while on their third or fourth instar. A few of them, under warmer temperature, died within 3 to 4 days, while in their same skin.

The concentration of the pathogen did not seem to have a definite influence over the disease virulence on older larvae. Larvae that were on their third instar or older until fully grown were properly infected by a suspension that contained 5 to 10 millions polyhedral bodies and succumbed within 4 to 7 days after being infected. These larvae consume more food and remain on their instar longer before casting their skin, than on previous instars. Third instar larvae died mostly on their fourth instar, but a good number of them succumbed while still in their same skin, when the temperature was around 30°C.

Fully grown larvae may live for 5 to 10 days before transforming into pupae, according to the temperature prevailing. When they were infected five to six days before pupation, they usually died before turning to pupae. When the temperature ranged between 30 and 34°C., infected fully grown larvae died within three days after the infection. Thus, some of the fully grown larvae escaped the infection if it took place late before pupation, and these emerged successfully. Others were able to carry the infection with their tissues and died a few days after pupation, with no definite sign of polyhedrosis.

VII. THE VIRULENCE OF THE DISEASE UNDER NATURAL CONDITIONS

Larvae that were collected from the field were usually in their fourth, or fifth instars, or fully grown larvae. Some of these larvae were already infected, since they succumb to the infection in spite of all precautions taken to prevent them catching an infection while bred in the laboratory. Thus, to realize the virulence of the polyhedral-virus infection among *Prodenia litura* in the field under the Egyptian natural conditions, it was necessary to secure sterilized containers and to use clean food that was not reached by the larvae in the field, e.g., the newly grown sprigs of the plants. Larvae were bred singly in carton cylinders to avoid the possibility that healthy larvae might devour cadavers of infected larvae; a phenomenon which was frequently observed and which raised the natural infectivity of the disease.

Most of the collected larvae that died due to polyhedrosis were fully grown, and some died during the pupal stage. During autumn and winter a huge number of larvae that were collected from berseem and were bred in the laboratory succumbed, but with no definite outside appearance of polyhedrosis. Their bodies contained either a mixture of polyhedral bodies and putrefying bacteria or only contained the bacteria with no apparent presence of polyhedral bodies. The mortality of a great number of *Prodenia* larvae that are bred in the laboratory during winter time is quite a common difficulty that faces those who try to keep the breeding running, in spite of all efforts to secure favourable temperature and humidity.

During the spring time, the berseem larvae were so healthy that very few of them showed the ailment of the polyhedral disease. These did not exceed five percent of the number of the singly bred larvae under 22 to 27°C.

During summer time, egg-masses of *Prodenia* that were laid on cotton leaves were left to hatch and the larvae were allowed to reach the second instar before breeding them singly. The disease inflicted about 10 to 20% of the larvae that were bred from egg-masses. In a few cases, the percentage of the inflicted larvae was much higher. This result supports the view that the virus disease can survive on the surface of the egg (Steinhäus, 1949, p. 448).

Late in summer, it was possible to collect larvae of different instars on maize plants that were severely infested by the pest. These larvae were bred singly and the mortality, due to the disease, reached over 25 percent of the collected larvae. This high rate of mortality among *Prodenia* larvae that were collected from maize may be due to high temperature and relative humidity prevailing during August. Also the high population of the pest at that time added to the virulence of the disease among the larvae.

VIII. THE INFECTIVITY OF A NON-INDIGENOUS POLYHEDROSIS-VIRUS DISEASE

The polyhedral-virus diseases of caterpillars are known for their specific relation with their hosts. This is explained by the fact that virus particles of diseases need to be grown inside living tissues of the host. Definite acquisition has been established between the host structures and the parasitic micro-organism. Lately, it has been claimed that certain polyhedral-virus diseases have proved to be infectious to several closely related species of hosts. *Prodenia litura* larvae were infected by a polyhedral-virus disease that infects *Prodenia praefica* larvae in California, to compare its virulence with that of the indigenous disease. The infected larvae were all fully grown, the temperature ranged between 28 to 34°C., and the suspension used for food contamination contained 5 to 10 millions polyhedral bodies. Under these conditions the infection of the indigenous disease was complete while the non-indigenous disease caused the infliction of about 70% of the infected larvae; the other 30% succeeded to escape the infection and to pupate. On the other hand, some of the dead larvae under the effect of the non-indigenous disease did not show full symptoms of polyhedrosis.

IX. HISTOLYSIS OF HOST TISSUES DUE TO POLYHEDROSIS

As previously mentioned, it was very hard discovering polyhedral bodies inside the first instar larvae. Smears of the second instar larvae that showed symptoms of the disease were found teeming with polyhedral bodies. Other inflicted instars showed the polyhedral bodies conspicuously in their smears. Smears from pupae that were thought to die under the effect of the disease failed to give a clear picture of polyhedral bodies due to presence of innumerable floating fat granules as an effect of histolytic and phagocytic processes.

The different stages in the formation of polyhedral bodies inside the nuclei of hypodermal and fat cells of the host were all determined, according to the findings of Hughes (1953) and Abul-Nasr (1954). The polyhedral body of *Prodenia litura* measures between 5-6 μ and, in most cases, has six sides (Fig. 4). The first tissue to be attacked by the infection is the mid-gut epithelium which is then regenerated through the nidi cells. The phenomenon of the mid-gut regeneration is responsible for keeping the alimentary canal intact and preserving the food inside it until a late stage of infection. Then polyhedral bodies are gradually formed inside the nuclei of the fat cells and the hypodermal cells of the inflicted larvae. At a later stage, tracheal epithelial cells and muscular cells are also infected. The first histolytic change that takes place in the cells of the inflicted tissue is that their

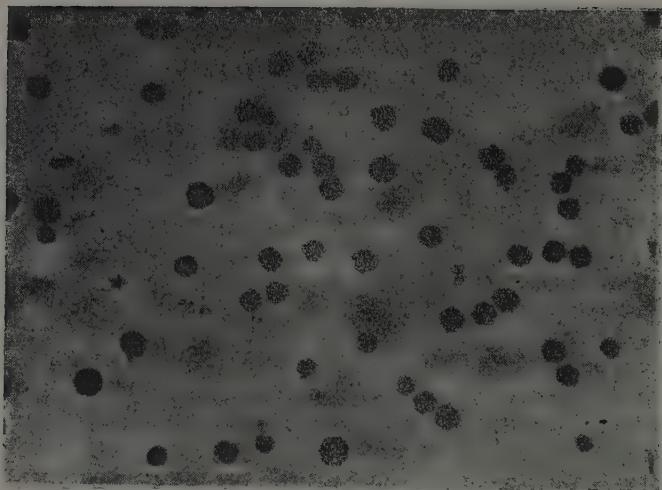


Fig. 4: Polyhedral bodies of virus-infected *Prodenia litura* larvae ($\times 2400$).

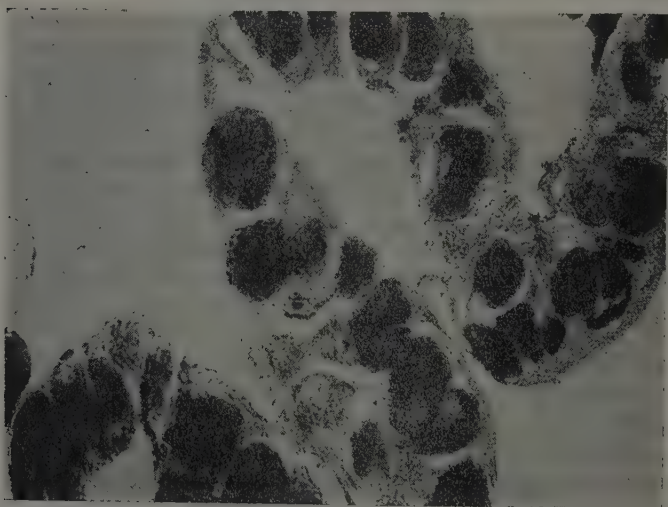


Fig. 5: Formation of polyhedral bodies inside the nuclei of virus-infected fat cells ($\times 460$).

nuclei start to grow larger and larger at the expense of the cytoplasm. At the same time, the chromatin material coagulates in a small number of solid masses that stain dark blue with iron haematoxylin (Fig.5). The chromatin masses drive to the middle of the nucleus where they unite, leaving a pale peripheral region. Then the chromatin mass starts to divide into very fine polyhedral bodies from the outside to the inside. The polyhedral bodies grow gradually in size until they fill up the whole space of its cell. Eventually, the cells that are bulged with the fully formed polyhedral bodies burst and evacuate their contents into the blood fluid (Fig. 6).

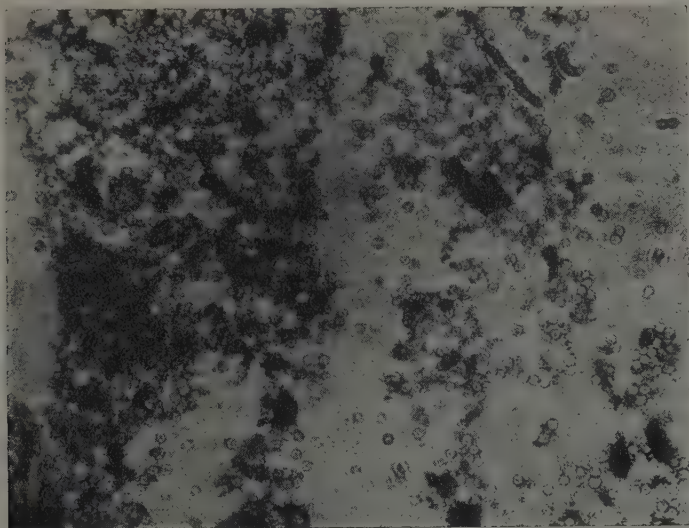


Fig. 6: Distribution of virus-infected cells and liberation of polyhedral bodies (x 460).

X. SUMMARY

1. A polyhedral virus disease infests *Prodenia litura* larvae in Egypt. The inficted larvae lose appetite, become sluggish, soft and flaccid, hang by the prolegs, disintegrate and liquify.

2. The virulence of the disease is greatly influenced by the increase of temperature and relative humidity. Also the incubation period of the pathogen is shortened under warm and humid conditions.

3. Healthy larvae can be inflicted in the laboratory by consuming contaminated food that is dipped in a suspension containing polyhedral bodies. A concentration of 5-10 millions polyhedra per milliliter of suspension is enough to cause complete infection among grown larvae. First and second

instar larvae need more concentrated suspension to cause considerable infection.

4. The disease is found in the Egyptian soil and can infect 5% of the *Prodenia litura* larvae in the field during spring time and up to 25 % during summer time.

5. A polyhedral-virus disease of *Prodenia preafica* was tried on *Prodenia litura* larvae. Its infectivity proved to be less virulent than the indigenous disease.

6. Polyhedral bodies are mainly formed inside the nuclei of mid-gut epithelium, fat body, hypoderm and blood cells.

XI. REFERENCES

- Abul-Nasr, S. (1954) : The formation of polyhedra in the gut epithelial cells of virus-infected insects (*Bull. Soc. Fouad Ier Ent.*, XXXVIII, pp. 383-395).
- Dudgeon, G. C. (1913) : A proposed method of controlling the ravages of leaf-eating caterpillars (*Bull. Ent. Res.*, IV, pp. 243-245).
- Gantès, E. (1910) : Les mesures de défense contre les vers du cotonnier (*Bull. Soc. Ent. Egypte*, II, pp. 47-49).
- Hughes, K. M. (1953) : The development of an insect virus within cells of its host (*Hilgardia*, XXII, No. 12, pp. 391-406).
- Metelnikov, S., and Metelnikov Jr., S. S. (1932) : Maladies des vers du coton (*Gelechia gossypiella* et *Prodenia litura*) (*Compt. Rend. Acad. Agr. France*, XVIII, pp. 203-207).
- Steinhaus, E. A. (1948) : Polyhedrosis (wilt disease) of the alfalfa caterpillar (*Jour. Econ. Ent.*, XLI, pp. 559-565).
- Steinhaus, E. A. (1949) : Principles of Insect Pathology (McGraw-Hill Book Co., New-York, 757 pages).
- Steinhaus, A. E. (1953) : Diseases of insects reared in the laboratory or insectary (Calif. Agric. Exp. Sta., Ext. Service, May 1953).
- Steinhaus, E. A., and Thompson, C. G. (1949) : Preliminary field tests using a polyhedrosis virus in the control of the alfalfa caterpillar (*Jour. Econ. Ent.*, XLII, pp. 301-305).
- Thompson, C. G., and Steinhaus, E. A. (1950) : Further tests using a polyhedrosis virus to control the alfalfa caterpillar (*Hilgardia*, XIX, No. 14, pp. 411-445).
- Willcocks, F. C., and Bahgat, S. (1937) : The insects and related pests of Egypt (I, part 2, page 591, Roy. Agric. Soc., Cairo).

Studies on Desert Insects in Egypt

II. ON THE GENERAL BIOLOGY OF *VERMILEO VERMILEO* L.

[Diptera : Rhagionidae]

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(with 10 Text-Figures and 2 Tables)

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I. Introduction. — II. Material, methods and technique. — III. The adult stage: 1, emergence; 2, habits of the adult; 3, mating; 4, oviposition; 5, longevity of the adult. — IV. The egg and larval stages. — V. The pupal stage: 1, duration of the pupal stage; 2, morphology of the pupa. — VI. Summary. — VII. References.

I. INTRODUCTION

In the first paper of this series (this Bulletin, pp. 279-299), the authors have given a detailed account of the worm-lion *Vermileo vermileo* L. including studies on its normal environment, behaviour and structure.

The present paper is a contribution to our knowledge of the general biology of the insect in its different stages. More stress has been laid on the adult which, contrary to the larva, does not feed, and is characterised by a very short longevity.

A review of the literature reveals that little is known about the biology of this species. Short notes on the worm-lions were given by De Geer (1752), and von Siebold (1861). Many years later, Wheeler (1931) published his comprehensive account of worm-lions including few remarks on *Vermileo vermileo*. More recently, the biology of this species received more attention by Buchner (1940).

The present work was carried out in the Department of Entomology, Faculty of Science, University of Cairo. The authors wish to express their sincere thanks to Professor H.C. Eflaton for his valuable suggestions.

II. MATERIAL, METHODS AND TECHNIQUE

Larvae obtained from the field were maintained in the laboratory throughout the year, in glass tubes each containing a single larva. Observations and experiments were conducted under laboratory and controlled conditions. In the former case, temperature and humidity were recorded by a thermohygrograph throughout the experimental period. In the latter case, four temperatures (16, 22, 27 and 33°C.) and four humidities (30, 50, 70 and 90% R.H.) were used. The desired relative humidities were obtained from different concentrations of KOH solutions prepared according to Buxton and Mellanby (1934) and Solomon (1951).

The adults just after emergence, were put in breeding cages 30 × 30 × 40 cm., and each contained a layer of very fine sand of about 4 mm. in thickness. Each group of adults emerging at the same hour were put in a separate cage so as to determine their exact longevity. Each mated couple was gently transferred just after mating to a separate cage. By this means, it was possible to watch the behaviour of both sexes and to determine their longevity and the duration of the different life processes such as the pre-oviposition period, mating, oviposition and post-oviposition periods, and the number of eggs laid by each female.

The sand provided to the females to lay eggs in was of very fine particles sieved from a stock brought from the field. The sieves used for this purpose contained 130 meshes per linear inch, the eggs were separated from the sand by sieves containing 78 meshes per linear inch.

The sand used in controlled experiments was previously heated to remove all the water contained in it, then transferred to the required temperatures and humidities for about two weeks to be conditioned.

Regular laboratory day and night observations during the breeding season (about forty days) were conducted, for taking records and studying the behaviour of the adults from emergence to death. The results on the longevity of the adults included in this work are accurate to one hour. In each case, the mean of ten experiments was taken.

III. THE ADULT STAGE

Adult *Vermileo* is a relatively small delicate bristless insect. The general colour of the body is yellowish-brown. The compound eyes are black and dichoptic in both sexes, and the rest of the head is dark brown with three darker broader stripes on the mesonotum. The fore and middle legs are lighter in colour and less stronger than the hind legs. The abdomen is brownish dorsally and yellowish ventrally. The abdominal tergum shows spotted irregular ornamentation.

The male (Fig. 1) is usually smaller than the female. The body length



Fig. 1 : Adult male of *Vermileo vermileo* L., x 5.

ranges between 5.7 to 7 mm. in the male and 5.5 to 8.4 mm. in the female. The wing expanse varies from 9.8 to 10.7 mm. in the male and from 9.8 to 14 mm. in the female.

1. Emergence

Adults of *Vermileo* are hardly seen in the field. On several visits to Wadi Digla during the year 1952, no adults were met with. Fortunately, during 1953 on the 22nd of April, four living adults (three females and one male), were caught. According to Wheeler (1931), no adult *Vermileo* of any species examined by previous workers was found in the field in its natural habitat with the exception of *Rondani*.

Under laboratory conditions, the majority of adults emerged in the early morning between 9 and 11 a.m., while none emerged later in the day.

In 1952, 1953 and 1954, adult emergence under laboratory conditions lasted for about one month during the breeding season. It commenced from the middle of March with very few adults emerging at first. The number then increased gradually and reached a peak towards the end of this month and gradually decreased again. Adult emergence stopped by about the middle of April (Fig. 2). During this period, the room temperature ranged from 17 to 22°C., with a mean of about 19.5°C. The relative humidity also varied between 34 and 56% with a mean of 45% R.H.

The adult leaves the pupal skin through a T-shaped slit found on the head and thorax. When newly emerged, the adult is pale yellow and has a soft body which hardens and darkens in colour within about one hour.

It was also observed that the number of emerging females exceeded

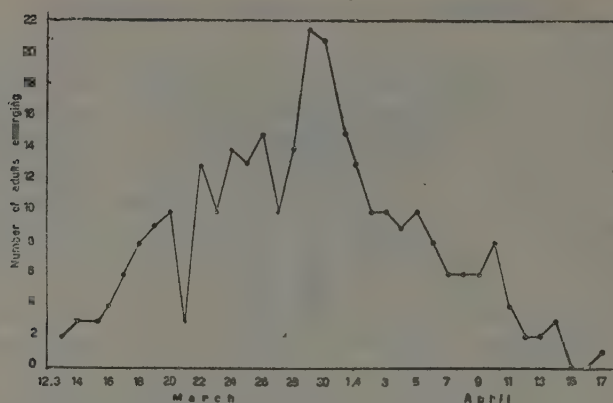


Fig. 2 : The rate of adult emergence from a stock of larvae kept under room conditions during the breeding season 1953.

that of males. Thus, of sixty adults emerging under room conditions, 40 were females and 20 were males.

2. Habits of the adult

The adults trapped in the field were seen between 11 and 12 o'clock in the morning. They were hovering charmingly in the air very near to the pitfalls of the larvae. When several sweepings were made in the open, no adults were trapped. One may assume that they generally do not go far from their breeding sites. This may be supported by the following.

- (1) The adults are delicate and unable to fly for long distances.
- (2) Being short-lived and produced in small numbers, the dispersal of the adults in the wadi may decrease the chances for both sexes to come across each other for mating.
- (3) If fertilized females go far from their breeding places and do not succeed in exploring suitable shaded situations for oviposition and for the development of the future larvae, they will be completely destroyed. The eggs and pupae, as shown by laboratory experiments, can withstand temperature not more than 30-32°C., while the surface temperature of the sand in exposed areas reaches on the average 45°C.

(4) Differences between physical conditions in the shade and in the open may act as barriers preventing the wandering of the adults.

During flight, the male usually curves its abdomen downwards while the female extends it.

In the laboratory it was observed that both sexes are positively photo-

tactic as they generally congregate near the illuminated side of the breeding cage. At rest the wings lie on the abdomen, either overlapping or widely separated.

It seems that the temperature prevailing during emergence has a great effect upon the activity of the adults. Those which emerged about the middle of March, when the temperature was somewhat low, about 16°C., were inactive and if undisturbed may remain motionless for a long time; while the adults which emerged towards the end of March and later, when the temperature was relatively higher, about 22°C., were distinctly active.

The adults persistently avoided liquid food with which they were provided, such as syrup, sugar solutions or honey. They even did not show any tendency to sip nectar from flowers when offered to them. Wheeler (1931) also noticed the same behaviour while Buchner (1940) recorded that the adults were seen feeding on nectar. At night, the adults are inactive and usually cling to the walls of the breeding cage and remain motionless.

3. Mating

Under laboratory conditions, it was noticed that adult males and females which emerged about the middle of March did not show any inclination to mate. Mating only occurred between adults emerged towards the end of March and later, when the temperature was higher, by about 3-4°C., at the end of this month than in the middle of it. This was true for the years 1952, 1953 and 1954. On the other hand, the relative humidity did not show any regular variation.

Mating took place 2 to 6 hours after emergence. The male first hovers around the female for sometime, then approaches it and comes to rest over its back curving its own abdomen downwards around the abdomen of the female. The male then grasps the ovipositor of the female from below with its forceps and for this purpose it raises its hind legs while at the same time the female inclines the apex of its abdomen slightly towards the male apparatus. The couple remains in this posture for about ten minutes, probably to ensure a complete hold in the right position. Afterwards, the male instead of remaining on the back of the female, rotates horizontally about 180° so as to lie in line with the female (Fig. 3).

Mating lasted from about 30 to 105 minutes. During this period the couple, unless disturbed, remains completely motionless on the surface of the sand or on the sides of the breeding cage.

During the process of mating, the wings of either sex form an acute angle with the long axis of the body. In some cases, however, the wings of the mating individuals may overlap during the process. Disturbance does not interrupt copulation, but merely causes the male and the female to fly



Fig. 3 : Male and female *Vermileo*, in copula.

while attached to each other. In this case the female usually takes the lead.

After copulation, the two sexes separate and the male flies actively in the air while the female rests for sometime before starting to oviposit. It was noticed that the male, unlike the female, showed certain tendency for repeated copulation.

4. Oviposition

Dissection of the abdomen of the female just after emergence, revealed that the ovaries contained mature eggs. The pre-oviposition period, i.e. the time elapsing from emergence to the beginning of oviposition, usually lasts from about four and a half hours to about seven hours.

Shortly after mating, the female rests on the surface of the sand for one or two hours after which it begins to lay eggs.

Before oviposition, the female hovers near the surface of the sand while testing it with the hind-tibiae. It then fixes itself to the sand with its fore and hind legs, and digs with its middle legs a small pit of about one millimetre in diameter and two millimetres in depth. At the same time, the female curves its abdomen downwards and anteriorly. During all these proceedings the abdomen vibrates rapidly, probably to help the eggs moving singly from the ovary towards the tip of the abdomen where they lie ready for deposition. Now the female thrusts an egg into the pit by a rapid stroke and, with the help of the fore and middle legs, it fills the pit with sand so as to hide the egg.

The place where an egg is laid is very typical, and assumes the shape of a small heap of sand with a depression in the centre surrounded by the clear tracks left by the legs of the female.

After an egg has been deposited, the female rests for a while (5-20 minutes) either on the sand or on the sides of the breeding cage. While resting, it scratches the extremity of its abdomen several times as if it were doing some massage before the next egg is laid.

The process of egg laying continues for a period ranging between 30 minutes to about four hours, after which the female remains motionless for several hours (about 4 to 19 hours). This latter period is the post-oviposition period.

The number of fertilised eggs laid by a single female varies from 8 to 30. Unfertilised eggs are uncommon, and when laid by unmated females they shrink after about three days.

5. Longevity of the adult

The adult *Vermileo* is a very short lived insect. It lives for about a day or two under laboratory conditions, but in no case, the longevity reached three days.

TABLE I

The effect of copulation on the longevity of adults
(average of ten experiments in each case)

TEMPERATURE IN °C.	LONGEVITY IN HOURS					
	FEMALE			MALE		
	Min.	Max.	Aver.	Min.	Max.	Aver.
Unmated	13	44	27.2	13	48	33.9
Mated	12	29	21.1	20	63	40.0

Table I shows the longevity of the adult under room conditions. It can be seen that the span of life of the unmated female ranged from 13 to 44 hours, with an average of 27.2 hours. The unmated males lived from 13 to 48 hours, with an average longevity of 33.9 hours. Comparing the two averages, it can be seen that males lived slightly longer than females. On the other hand, mated females lived shorter than unmated ones, while the mated males lived longer than unmated ones (Table I). It is also clear that among mated individuals, the average longevity of the male was nearly twice that of the female.

IV. THE EGG AND LARVAL STAGES

The egg (Fig. 4) is oval in shape with the narrow end more or less trunc-

ate. It measures from 0.58 to 0.78 mm. in length, and 0.30 to 0.40 mm. in width.

When newly deposited, the egg is more or less transparent and pale creamish in colour. After about three days it becomes opaque and assumes a whitish colour. The egg is always surrounded by scattered fine sand particles stuck to its surface. Usually, this sand is not easily removed even if the egg is immersed in water for many hours. Under high magnification, the micro-sculpture of the egg-shell is neatly seen.

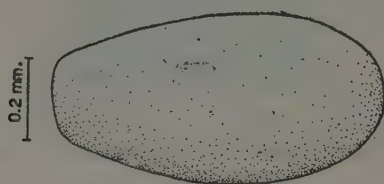


Fig. 4 : Egg of *Vermileo vermileo*.

A day or two before hatching, a dark spot appears towards the narrow end of the egg. This spot indicates the head skeleton of the first stage larva.

Under laboratory conditions, it was observed that all the eggs laid on the same day, either by one or many females, usually hatched at the same date. For instance, all the eggs deposited on the 28th of March hatched on the 6th of April 1953, and all the eggs deposited on the 3rd of April hatched on the 13th of the same month. Thus, under laboratory conditions, the incubation period lasted from 9 to 10 days. During this period, the room temperature varied from 22 to 25.5 °C.

The possible effect of temperature and humidity on the incubation period was tested in a series of experiments, from which it was found that the most effective factor is temperature, while humidity has no apparent effect. Thus, keeping the temperature constant and varying the relative humidity, did not produce any appreciable effect on the incubation period. On the other hand, temperature variation showed a remarkable effect on this period. The length of the incubation period decreased with increased temperature. At low temperature, e.g. at 16°C., the incubation period was comparatively long and the eggs hatched after 28 days. At 22 °C., they hatched after 11 days, at 27°C. after 7 days, while at 30°C. it lasted only 6 days. Above 30°C., e.g. at 33°C., the eggs shrank and did not hatch. It was also found that increasing temperature from 27 to 30°C. seemed to have no appreciable effect on the incubation period as there was only a slight difference between that period at 27 and 30°C.

It may also be pointed out that no mortality was recorded among the eggs except in very rare cases, nearly all the eggs succeeded to hatch.

Under room conditions, hatching took place at any time of the day. Before hatching, the larva can be seen inside the egg working its way through the chorion by means of its mouth parts and hard head skeleton. A small pore is then made towards the narrow end of the egg and the dark brown head of the larva appears followed slowly by the rest of the body. When the greatest part of the body becomes free, the larva starts immediately to penetrate the sand while trying gradually to get rid of the egg-shell. Larvae encountering solid surfaces on hatching, always failed to free themselves from their egg-shells.

A day or so after hatching, the larva constructs in the sand a small pit about 2 mm. in width and about the same in depth. The size of the pitfall varies with the size and age of the larva. The larvae usually construct their pitfalls very near to each other, in a cluster commonly known as colony (Fig.5).

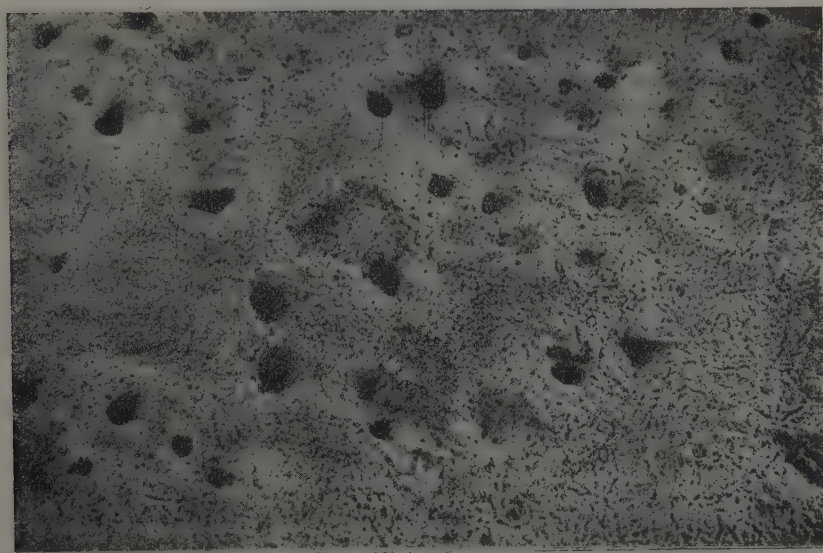


Fig. 5 : Colony of *Vermileo* larvae showing the conical pitfalls and the sinuous grooves made by the larvae in the surface of sand.

When the larvae are sieved from the sand, they feign death and assume a U-shaped position (Fig. 6), and leap when mechanically irritated. They feed readily on aphids and small soft-bodied insects. The prey is sucked and the remains are thrown outside the pitfall.

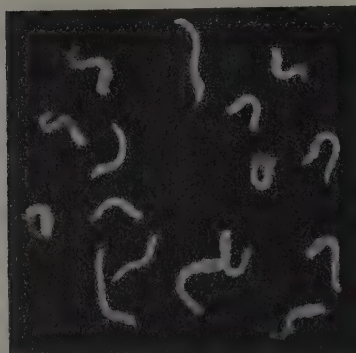


Fig. 6 : Larvae of *Vermileo vermileo*.

The larval growth is very slow, as some of the first stage larvae kept under room conditions reached 5 mm. in length after about 18 months.

In the field, larvae of varying sizes were found throughout the year. Some of them attained large sizes by the advent of the breeding season, about February. Towards the end of the breeding season and later (March and April), it was interesting to observe the minute pits of newly hatched larvae aggregated in clusters beside the well developed conical pits made by the larger over-wintering larvae. These observations, together with the fact that adults are produced once a year, indicate that the larvae may require more than one year, at least two years to complete their life-cycle, a point which needs further investigation and will be conducted in the future.

Under room conditions, the larvae showed signs of pupation by the end of February. Prior to pupation, the larva generally stops feeding, leaves its pit and conceals itself in the sand. It then curves the anterior part of its body for several times so as to squeeze the contents of the alimentary canal in the hind part of the mid-gut. Then the junction between the mid-gut and hind-gut becomes opened and the contents of the gut are evacuated through the anal opening in the form of one or two hard spherical blackish pellets. After this process, the body-shape of the larva undergoes certain changes. It becomes somewhat reddish in colour, loses its transparency, and becomes opaque. But, the characteristic behaviour of the larva such as leaping in the air when mechanically irritated, feigning death, etc., are still retained. It can also penetrate the sand, but never constructs pits.

The larva changes into a pupa, generally four to six days after evacuating the contents of the alimentary canal. The larval skin always remains firmly attached to the last abdominal segment of the pupa in the form of a folded tube.

Most larvae normally passed the summer in feeding and repairing their pits. Some of them, however, neglected their pits during part of the summer, probably taking a period of rest during which no food was taken, but began their normal activity again by the advent of winter.

V. THE PUPAL STAGE

1. Duration of the pupal stage

After the larva is transformed into a pupa, the latter makes its way through the sand by a vertical movement with the head directed upwards. Then, it either remains in that vertical position with the head only visible from above, or it completely comes to lie over the surface of the sand (Fig.7).

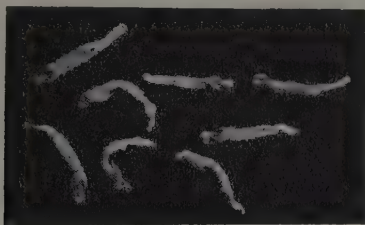


Fig. 7 : Unearthed pupae of *Vermileo vermileo*.

On an excursion to Wadi Digla on 28.iii.1952, a number of pupae together with some pupal skins were found, but it was not possible to decide the exact date of their occurrence in the field. Fortunately, in the breeding season during 1953, it was possible to trace the beginning of pupation in the natural habitat, as on 12.iii.1953, a large number of pre-pupating larvae, about forty, were collected. Continuous search the whole day, revealed the complete absence of pupae in the region. The sudden rise in temperature on the 9th, 10th and 11th of March, may have stimulated the larvae to pupate. During an excursion on 22.iv.1953, neither pupae nor pre-pupating larvae were found in Wadi Digla. These observations indicated that the breeding season of 1953 was at an end, and that the duration of the pupal stage in the field in that year lasted about 40 days. During this period, the shade temperature ranged between a minimum of 5.3 and a maximum of 36°C., while the mean relative humidity was 44.8%. Under laboratory conditions, it was observed that pupation started to take place on about the 20th of February. It reached its peak on about the 8th of March, while by the beginning of April the mature larvae have been changed into pupae (Fig. 8). During this period, the room temperature ranged between 17 and

27°C., with a mean of 21.1°C. The relative humidity also varied from 21 to 57%, with a mean of 42.2%. Under such conditions, the pupal stage lasted from 20 to 22 days.

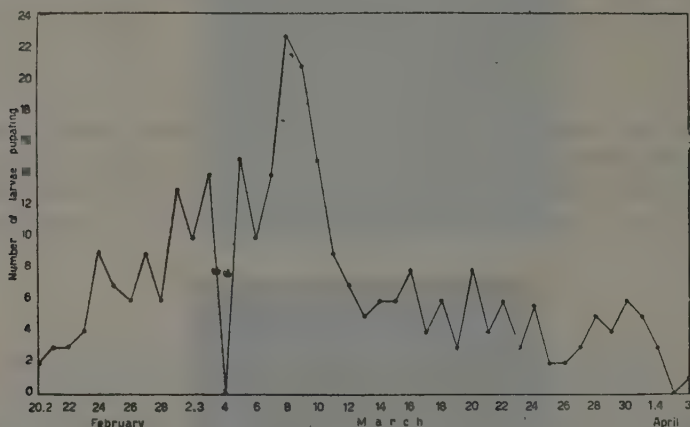


Fig. 8 : The rate of pupation from a stock of larvae kept under room conditions during the breeding season 1953.

Under controlled temperature and humidity conditions it was found, as in the case of the eggs, that changing the relative humidity while keeping the temperature constant, produced no appreciable effect on the duration of the pupal stage. This was always the case with regard to all temperatures tested. The only difference noticed was among the pupae kept under a constant temperature of 16°C. and varying relative humidities. An average minimum duration of the pupal stage of 31 days was obtained at 90% R.H., and a maximum duration of 34.3 days occurred at 70% R.H. At lower humidities, i.e. 50 and 30% R.H., the duration ranged between the two (32.7 days at 50% R.H. and 33.2 days at 30% R.H.). It can be seen that

TABLE II

Effect of temperature and humidity on the pupal stage

TEMPERATURE IN °C.	MEAN PUPAL DURATION IN DAYS UNDER DIFFERENT R.H.			
	30%	50%	70%	90%
16	33.2	32.7	34.3	31.0
22	14.6	14.8	14.4	14.2
27	9.2	9.6	9.4	9.2
33	died	died	died	died

these figures do not give any regular sequence and this difference may not be of much significance. Under the other temperature conditions, changing the relative humidity did not affect the duration of the pupal stage (Table II). Now, when we come to consider the change of temperature while keeping the humidity constant, it can be observed that the temperature may be regarded as an important factor affecting the duration of this stage. Thus, a marked decrease in the number of days necessary for the transformation of the pupa to the adult was noticed when the temperature was raised from 16 to 27°C. At 16°C., the number of days required was about 33 days compared with about 14.5 days at 22°C., and only about 9.5 days at 27°C. Under a higher temperature of 33°C., all pupae under all ranges of relative humidity, as in the case of the eggs, died and no emergence occurred.

It may be pointed out that at 27°C., a high mortality of the pupae kept under 70 and 90% R.H., was recorded. This may be explained by the fact that under these conditions the sand retains larger quantities of water and becomes compact, thus making it difficult for the pupa to make its way through it when the adult is ready to emerge. It may also be due to the fact that the very high moisture content of the sand, which sometimes amounts to saturation, has a direct fatal effect on the pupa.

When the adult is ready to emerge, the pupa exposes its head and thorax and often a part of the abdomen from the sand so as to facilitate the emergence of the delicate imago.

The activity of the pupa is not limited to this process, but pupae were often observed standing vertically in the sand with their heads just exposed and making circles with the anterior parts of their bodies, with the result that small funnel-shaped pits similar to those of the larvae were produced. Moreover, some pupae were also able to leap when mechanically irritated.

2. Morphology of the pupa

The pupa (Fig. 9) is typically orthorrhaphous in form. It measures from 5 to 7 mm. in length. The body is somewhat arched dorsally and recurved ventrally. When newly formed, the body is yellowish in colour; after about one day the head and thorax assume a dark brown colour and the abdomen becomes greyish.

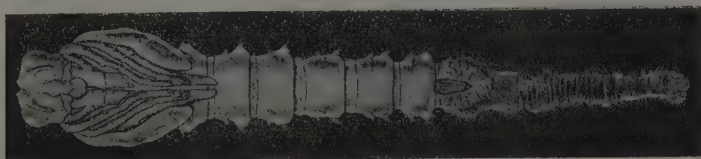


Fig. 9 : Pupa of *Vermileo vermileo*.

The head and thorax are closely joined to each other and are considerably broader than the abdomen. The large compound eyes are situated within their sheaths (Fig. 10) on the antero-lateral regions of the head. The bases of the antennae arise between the eyes. The antennal sheaths are elongated, pointed apically, and extend beyond the posterior margin of the eyes.

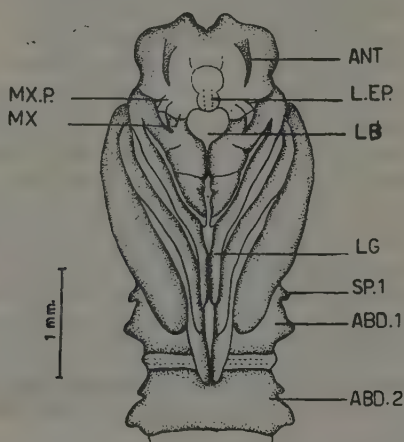


Fig. 10 : Head and thorax of the pupa, ventral view 1 (ABD. and ABD. 2, first and second abdominal segments : ANT, antenna; LB, labium; LG, legs; L.E.P., labrum epipharynx; MX, maxilla; MX.P., maxillary palp; SP. 1., first abdominal spiracle).

The sheaths of the mouth parts occupy a mid-ventral position and extend to the sheath of the fore-legs. The sheaths of the maxillary palps (MX.P.) are widely divergent and separated by the sheath of the labrum epipharynx (L.E.P.), maxillae (MX) and labium (LB).

The wing sheaths extend ventrally to the first abdominal segment. The inner margins of the wing sheaths enclose a space occupied by the legs closely folded within their sheaths. The sheaths of the legs (LG) are separated by conspicuous sutures. On the dorso-lateral regions of the thorax, near the anterior end, are located the thoracic spiracles. The metathorax is a narrow strip on the dorsal side of the body.

The abdomen is eight-segmented and tapers towards its posterior end. On the inter-segmental skin are two transverse lines composed of very small roughened areas. Near the antero-lateral regions of the segments 1-7, are situated the abdominal spiracles which are carried on backwardly directed protrusions from the sides of the abdomen.

The skin of the last larval instar remains firmly attached to the last abdominal segment of the pupa throughout the pupal stage.

VI. SUMMARY

Adults of *Vermileo vermileo* emerged under laboratory conditions (17-22°C and 34-56% R.H.) between 5 and 8 a.m. Adult emergence continued in the laboratory for about one month from the middle of March to the middle of April. In the field, the breeding season continued from about the middle of March to about the end of April (5.3-36°C. and 44.8% R.H.). The adults in the field do not seem to go far from the breeding places.

Mating took place 2 to 6 hours after emergence and lasted from 30 to 105 minutes. The male, unlike the female, showed certain tendency for repeated copulation. Rise in temperature seems to induce mating.

The pre-oviposition period lasts from about 4.30 to about 7 hours. Oviposition begins two hours after mating. The eggs are laid singly in pits made by the female in the sand, then covered by a thin layer of sand. The time elapsing between depositing two eggs successively varies from 5 to 20 minutes. The oviposition period lasts from about thirty minutes to about 4 hours. The post-oviposition period is about 4 to 19 hours. The number of eggs laid by a single female varies from 8 to 30.

The adult is very short-lived. The longevity of unmated females varies from 13 to 44 hours, while that of unmated males extends from 13 to 48 hours. Mated females lived shorter than unmated ones, while the mated males lived longer than unmated ones. The average longevity of the mated male was nearly twice that of the female. During the whole life of the adult, no food is taken.

Under laboratory conditions (20-25.5°C.), the incubation period lasted from 9 to 10 days. Temperature is an important factor influencing the incubation period, which was 28 days at 16°C., 11 days at 22°C., 7 days at 27°C., and 6 days at 30°C. At 33°C., all eggs dried up and no emergence occurred. The relative humidity had no effect on the incubation period.

Under laboratory conditions, pupation began towards the end of February. The pupal stage lasted from 20 to 22 days. Its duration is greatly influenced by temperature, but not by relative humidity. It is about 31 days at 16°C., 14 days at 22°C., and 9 days at 27°C.

VII. REFERENCES

- Buchner, P. (1940): Ueber den Wurm-lowen (*Vermileo vermileo*) (*Natur. u. Volk*, Frankfurt a.M., LXX, pp. 116-131, 14 figs).
Buxton, P.A., and Mellanby, K. (1934): The measurement and control of humidity (*Bull. Ent. Res.*, XXV, pp. 171-175).
De Geer, C. (1752): Ron om mask-Lejonet (*Vetensk. Akad. Handl.*, pp. 180-192, 261-265, 1 pl.).
Siebold, C.T.E. von (1861): Ueber die Larve von *Leptis vermileo*

(*Versam. Deutsch. Naturf. u. Aerzte in Koenigsberg*, XXXV, 1860, pp. 105-107).

S o l o m o n , M.E. (1951) : Control of humidity with potassium hydroxide, sulphuric acid or other solutions (*Bull. Ent. Res.*, XLII, pp. 543-554).

W h e e l e r , W.M. (1931) : Demons of the dust (Kegan Paul, Trench, Trubner and Co., xviii+378 pages, pl., 49 figs., London).

Histological studies on some dermal structures of *Planococcus citri* (Risso)

[Coccoidea : Pseudococcidae]

(with 4 Text-Figures)

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INTRODUCTION

Since confusion exists in literature about the real nature of some dermal structures of mealy-bugs, histological studies were made in an attempt to submit some contribution to this subject. Another stimulus for the work was the fact that these structures are closely connected with the exterior of the body or at least having an exterior indication and each type has its own shape and rather constant distribution that render them very significant in modern taxonomy.

Dr. K. T. Stringer (Shepherd College, West Virginia), generously aided this histological study, while Dr. N. E. Phillips (University of Maryland) provided the necessary facilities for the work. The problem was suggested by Prof. H. S. McConnell, of the same University, who also suggested many helpful points in the technique. The writer is grateful to these professors.

MATERIAL and TECHNIQUE

The mealy-bugs sectioned are of the species *Planococcus citri* (Risso). The technique followed in this study is essentially the same used by Pollister (1937) in studying the glands of *Pseudococcus maritimus* (Ehrhorn). The main steps that gave the best results are as follows :

(1) Touching the bugs with a brush that has been dipped in absolute alcohol to wet and partially remove the wax covering in order to assure good fixation.

- (2) Fixing in Allen's B 15 at about 78°F. for two hours.
- (3) Embedding in paraffin after the material has been completely dehydrated in alcohol and cleared in cedar oil.
- (4) Sectioning at 5 or 10 microns.
- (5) Staining with iron haematoxylin and counterstaining with eosin. Delafield's haematoxylin was easier to apply and gave as satisfactory staining results as Heidenhain's.
- (6) Blood cells, in smears of blood and in ostiole excretion were stained nicely with Wright's blood stain.

HISTOLOGY

The dermal structures can be classified as follows :

I. The wax-secreting glands, consisting of : (1) the trilobular disc-pore glands, (2) the multilobular disc-pore glands, and (3) the tubular duct glands.

II. The ostioles.

III. The circulus.

Figure 1 represents the distribution and external appearance of the above mentioned structures as they look in a microscopic preparation of a typical adult female mealy-bug from the genus *Planococcus* Ferris.

A longitudinal section through a trilobular disc-pore gland is given in Figure 2 A. The gland is usually pear-shaped, but may become more elongated wherever the glands are crowded, such as near the cerarian setae. It is composed of a central cell with a rather large nucleus and a clear reservoir in which exists a merging system of tubes which unite into a single efferent duct that leads to the central aperture of the external pore. The central cell is partially surrounded with three peripheral cells, each of which has in its cytoplasm a duct-like vacuole that follows a slightly spiral course near its external termination. The opening of these courses form the three loculi of the external opening. The neck portion of the gland is formed of a single neck-cell. The two small nuclei of the central cell which Pollister found in *Pseudococcus maritimus* were not demonstrated in *Planococcus citri*.

Matheson reported that these glands secrete the small coiled wax threads that cover the entire body. This conclusion appears to be correct since such coils are frequently observed protruding from trilobular disc-pores in ordinary preparations under-treated with caustic potash.

Figure 2 B illustrates a longitudinal section through a multilobular disc-pore gland, while Figure 2 Bd represents the highly characteristic multilobular disc-pore as seen from below, and Figure 2 Be shows the opening as it should appear in a sagittal section.

The gland is composed of a small central cell imbedded among ten larger peripheral cells. The central cell of this type of gland is devoid of any reservoir or internal duct system. It has only a clear area in the cytoplasm that

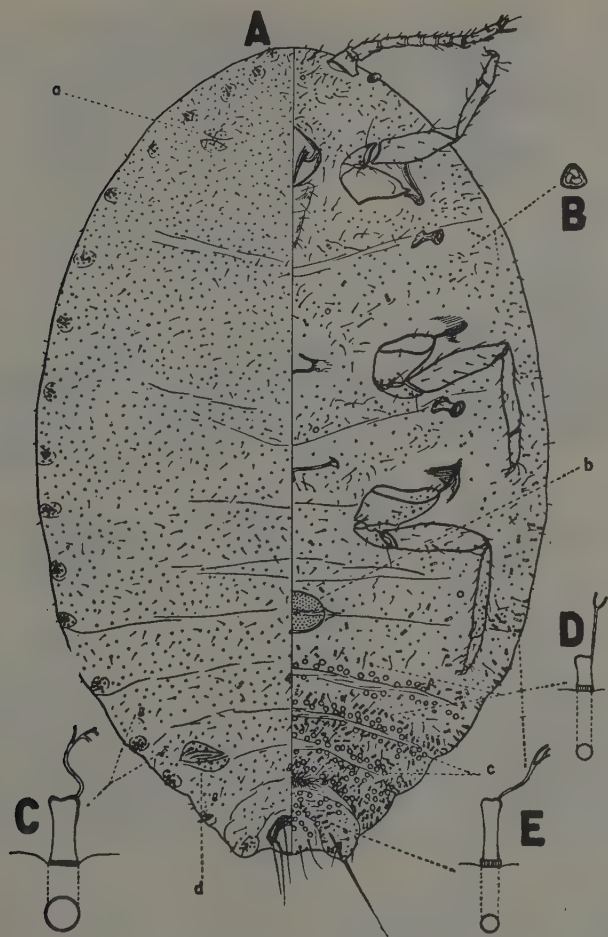


Fig. 1: (A) Typical mealy-bug of the Genus *Planococcus* Ferris, x 60 (a, anterior ostiole b, circulus; c, multilocular pores; d, posterior ostiole). — (B) Trilocular pores, x 2000. — (C) Dorsal tubular duct, x 2000. — (D) and (E) Ventral tubular ducts (different sizes), x 2000.

leads directly to the central opening of the external pore. The peripheral cells have vacuolated zones leading to the ten loculi surrounding the central opening of a multilocular disc-pore. The neck portion of the gland is formed of a single neck-cell.

Matheson stated that those glands undoubtedly secrete much of the waxy threads which form the egg-sac since they are very abundant about

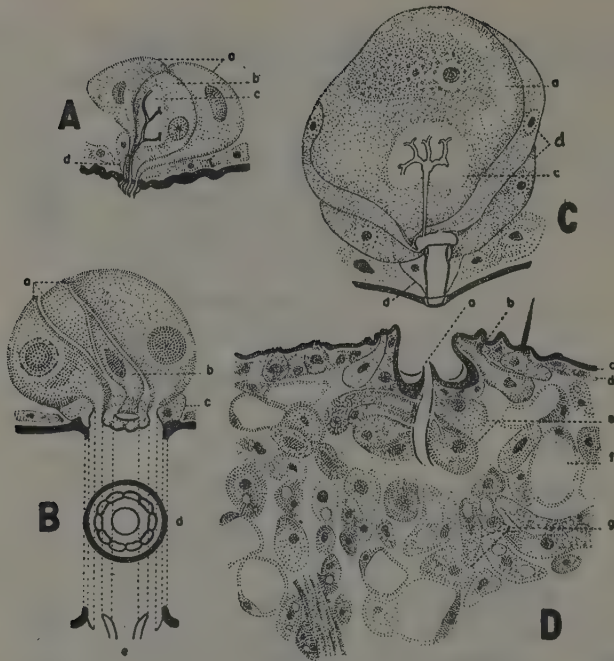


Fig. 2 : (A) Longitudinal section of a trilocular gland, x 2000 (a, peripheral cells; b, central cell; c, internal reservoir and duct system; d, neck cell).— (B) Longitudinal section of a multilocular gland, x 2000 (a, peripheral cells; b, central cell; c, neck cell; d, pore of multilocular gland as seen from below; e, sagittal section of the pore). — (C) Longitudinal section of a tubular gland, x 2000 (a, central cell; b, peripheral cells; c, central reservoir and duct system; d, neck cell). — (D) Longitudinal section through the ostiole, x 600 (a, opening; b, trilocular gland; c, cuticle; d, hypodermis; e, glandular cells; f, fat cell; g, oenocytes).

the genital opening. This statement is acceptable specially because no other explanation has been offered.

A longitudinal section illustrating the structure of a tubular-duct gland is given in Figure 2C. This gland possesses a central cell surrounded with ten peripheral cells. The central cell of this type of gland is much larger than the peripheral cells and has a very large nucleus and a clear reservoir including a merging duct system that lead to one efferent duct. The duct system is chitinous and usually shows up in ordinary preparations treated with caustic potash and stained with fuchsin. The efferent duct leads to the inner end of a chitinized tube that opens at the surface of the cuticle. The inner end of the this tube is slightly enlarged and receives the clear pathways leading from the cytoplasm of the peripheral cells. The

neck of the gland is composed of a neck-cell surrounding the chitinized tube. Pollister illustrated and described two additional small nuclei in the central cell of such glands in *Pseudococcus maritimus*, but these were not demonstrated in *Planococcus citri*.

It is assumed that the tubular duct glands secrete the long threads of the lateral waxy filaments and egg sac.

The ostioles consist of a transverse pair of dorsal slit-like openings near the head area, and a similar pair near the posterior end of the abdomen (Fig. 1 Aa and Ad). The edges of the openings are evaginated to form the anterior and posterior lips, usually beset with setae and trilocular disc-pores. The anterior pair apparently belongs to the prothorax, and the posterior pair is present in the sub-marginal areas of the seventh abdominal segment.

When the living bug is stimulated by touching with a probe, a globule is ejected from one or more of the four ostioles. This globule quickly acquires a viscous consistency. Since the terms "reflex bleeding" and "autohemorrhage" have been applied to this and somewhat similar phenomena in other insects, smears from ejected globules and smears from the bug's blood were prepared. A comparison of these two types of smears was kindly made by Dr. S.C. Munson of the George Washington University, and by Dr. J.C. Jones of the National Microbiological Institute, N.I.H., Bethesda. Their results show that the globule from the ostiole had a higher proportion of plasmatocytes than blood samples from the hemocoel. In addition to this difference, the ostiole globule also contains some amorphous substance that may be fatty in nature.

A longitudinal section through the ostiole (Fig. 2D) shows greatly enlarged cells along the deep walls of the opening. These cells are rather rounded with more or less granular cytoplasm and having clearer pathways leading to somewhat translucent pores in the thin integument lining the deep groove of the opening. These features suggest a glandular function for such cells. The amorphous substance in the discharged globule is probably an exudate from these cells through the translucent pores of the groove walls, since no duct system was found in this area. It is possible that the blood, on its way out, becomes mixed with that exudate. This idea is different from that of M u r d o c k who reported that the discharge through the ostioles is merely the body fluid.

Since dorsoventral muscles have been demonstrated near the lateral ends of the ostioles, M u r d o c k's conclusion, that the fluid is forced out of the ostioles by an increased internal pressure due to sharp contraction of those muscles, appears to be correct.

The circulus is a term applied, in mealy-bug morphology, to a ventral median sclerotized ring enclosing an area which is always free from pores and setae. When present in *Planococcus*, it is located in the interseg-

mental fold between the fourth and fifth abdominal segments and usually rather oval in shape (Fig. 1 Ab). Histological sections showed that the ring bordering the circulus is demonstrated by an increase in the cuticular sclerotization. The area enclosed by this ring is divided, in the longitudinal section (Fig. 4), by a deep fold which corresponds to the intersegmental fold between the fourth and the fifth abdominal segments.

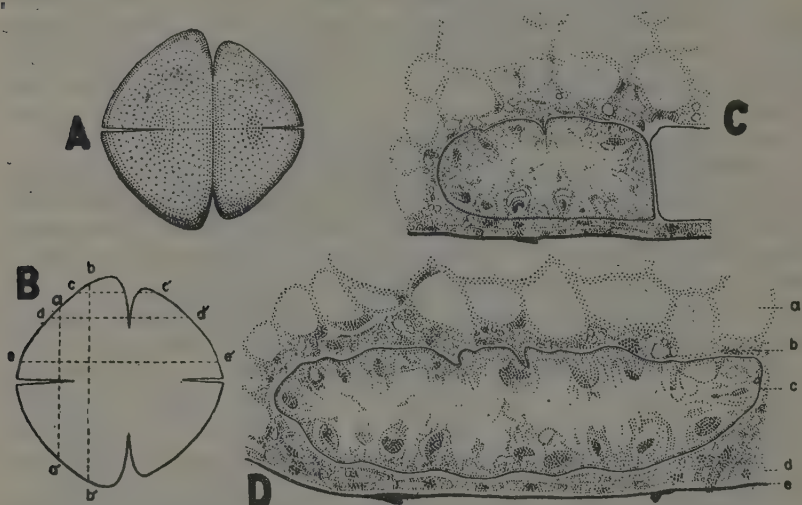


Fig. 3 : (A) Diagrammatic representation of the glandular structure existing above the integument at the circulus region , x 150. — (B) Optical section at about the centre of the same structure, x 150 (a-a, b-b, c-c, d-d, and e-e, levels of the following illustrated sections. — (C) Crosssection at level a-a, x 400. — (D) Cross-section at level b-b, x 400 (a, fat tissue; b, blood; c, glandular structure; d, hypodermis; e, cuticle).

Just above this area there is a structure that has not been noticed before, to which the name “epicirculus body” is proposed. When this structure was reconstructed from a series of sections, it appeared as in Figure 3 A. It measures about 200 microns in length, about the same in breadth, and about 50 microns in depth. Cross-sections illustrated in Figure 3 C and D, and longitudinal sections in Figure 4 A, B and C are provided to establish a new anatomical fact (Fig. 3 C, and Fig. 4 A and B illustrate only a part of the structure). The levels of the illustrated sections are represented by dotted lines in the optical section in Figure 3 B.

The real nature of the histological constituents and the physiological properties of this structure need more investigation. However, the structure looks glandular since it is lined with glandular-like cells at different stages of secretion. The appearance of these stages give the impression

that these cells are glands of the holocrine type though no regenerative cells were detected.

In general, the epicirculus body is probably an endocrine gland since there is no apparent communication with either the exterior or the interior of the mealy-bug. It is assumed that the secretions are discharged into the sinus of the structure and diffused out by osmosis to the surrounding blood.

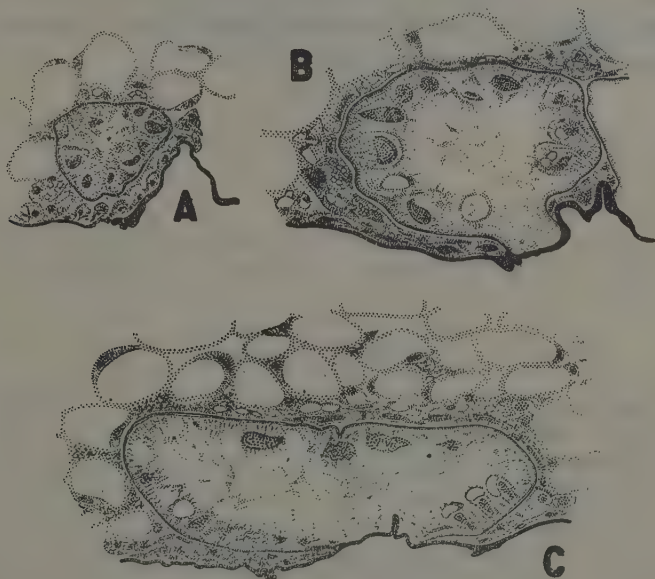


Fig. 4 : (A) Longitudinal section at level c-c in Figure 3B, x 700. — (B) Longitudinal section at level d-d, x 700. — (C) Longitudinal section at level e-e, x 300.

SUMMARY

In this paper, some dermal structures of *Planococcus citri* (Risso) are studied in detail. These structures are the trilocular and the multilocular disc-pore glands, the tubular duct glands, the ostioles, and the circulus.

The histological constituents of the ostioles suggest certain glandular function for them. This suggestion is supported by a microscopic comparison between the ostioles' excretion and the haemolymph.

Through the course of study, a glandular-like structure was discovered just above the circulus. The name "epicirculus body" is here proposed for this structure.

LITERATURE

- Ferris, G. F., and Murdock, G. E. (1936) : Contributions to the knowledge of the Coccoidea (Homoptera). III. Certain dermal structures of Pseudococcidae (*Microentomology*, I (4), pp. 115-122, figs. 83-85).
- Matheson, R. (1923) : The wax-secreting glands of *Pseudococcus citri* Risso (*Ann. Ent. Soc. Amer.*, XVI pp. 50-56).
- Pollister, P. F. (1937) : The structure and development of wax glands of *Pseudococcus maritimus* (Homoptera, Coccidae) (*Quarterly Journal Microscopical Science*, LXXX(1), pp. 127-152).
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The thoracic sclerotization of coccid adult males as a promising taxonomic character

[Coccoidea]

(with 9 Text-Figures)

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INTRODUCTION

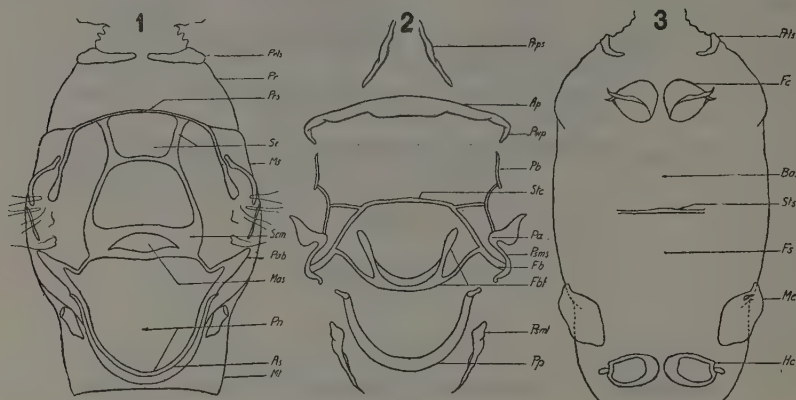
Classification of the super-family Coccoidea has been almost entirely dependent upon the morphological characters of the adult female except in few cases only, where other instars were taken into consideration. The availability of females might be, to a certain extent, responsible of this situation in spite of the fact that males proved to be helpful in classifying the higher categories of Coccoidea. Several authors, however, feel that certain morphological features of the adult male could be of value as generic or even specific characters. One of these features is the sclerotized frame-work of the thorax, which led Morrison to state that, undoubtedly, a comparative study of the thoracic sclerites would be profitable taxonomically.

Attempts towards this aim have yet been limited, probably due to the difficulties expected in such type of work, or to the lack of sufficient accumulated material. In the present work, a step is taken towards further understanding of the thorax of coccid males and how promising it could be in the field of taxonomy.

MATERIAL and TECHNIQUE

The males examined for this project belong to four families of Coccoidea, as follows : *Pulvinaria ericicola* McConnell (Figs. 1-3) [Coccidae]; *Pseudococcus vitis* (Nied.) (Figs. 4 and 5) [Pseudococcidae]; two *Aclerda* spec. [Aclerdidae], the males of one species of which are wingless (Fig. 6), while those of the other

are winged (Fig. 7); and two species from Diaspididae, *Quadraspidiotus perniciosus* (Comst.) (Fig. 8) from tribe Aspidiotini, and *Leucaspis japonica* Ckll. (Fig. 9) from tribe Diaspidini.



Pulvinaria ericicola McConnell

Fig. 1 : Thorax of the adult male, dorsal view. — Fig. 2 : Thorax of the adult male, lateral and internal sclerites. — Fig. 3 : Thorax of the adult males, ventral surface. — $\times 112.5$.

(*Ap*, anterior phragma (precosta); *As*, antecostal suture; *Bas*, basisternum; *Fb*, furcal bridge (postcoxal bridge); *Fbf*, furca and base of furca; *Fc*, fore coxa; *Fs*, furcasternum (furcisternum); *Hc*, hind coxa; *Mas*, membranous area of scutellum; *Mc*, mid coxa; *Ms*, mesothorax; *Mt*, metathorax; *Pa*, pleural apophysis (prominent apodeme); *Pab*, postalar bridge; *Pb*, pleural bridge (precoxal bridge); *Pn*, postnotum (postscutellum); *Pp*, posterior phragma (posterior diaphragm); *Pr*, prothorax; *Prs*, prescutum (praescutum); *Prtls*, prothoracic suture; *Psms*, pleural sclerite of mesothorax; *Psmt*, pleural sclerite of metathorax; *Pspr*, pleural sclerite of prothorax; *Pwp*, prealar wing process; *Sc*, scutum; *Scm*, scutellum; *Stc*, sternacosta; *Sts*, sternacostal suture).

The microscopic preparations were fundamentally obtained by heating in caustic potash until the specimens become clear enough, washing with acidate water, dehydrating in alcohol, staining in fuchsin, then clearing with dioxane and mounting in balsam dissolved in dioxane. Basic fuchsin is preferred for the staining, which should be rather heavy to facilitate the examination of sclerites. It is a good practice to use excess of balsam for mounting in order to avoid a thoracic collapse, which might cause a change in the normal position of the sclerites. Specimens are usually mounted with dorsal surface up. However, mounting few specimens in other positions is advisable to study the relationship among the various sclerites.

Drawings are generally made from a dorsal view, except in Figure 5 which represents a dorso-lateral view for the thorax of *P. vitis*, submitted for more illustration of the relationship among the different sclerites. For further demonstration, the thoracic sclerites of *Pulvinaria ericicola* are illustrated in

three figures, one of which shows the sclerites that appear on the dorsum, the next shows the internal and lateral sclerites, while the last represents the ventral surface. To avoid extra superposition in the winged forms, the base of right wing is eliminated from the drawings.

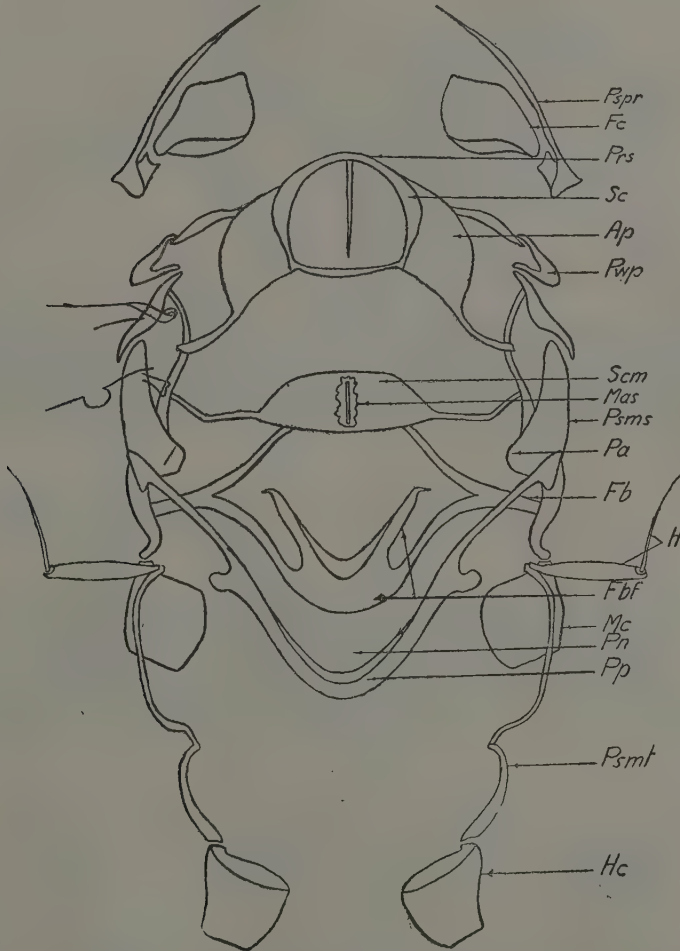


Fig. 4 : *Pseudococcus vitis* (Nied.), thorax of the adult male, dorsal view, $\times 190$ (*Ap*, anterior phragma; *Fb*, furcal bridge; *Fbf*, furca and base of furca; *Fc*, fore coxa; *H*, haltere; *Hc*, hind coxa; *Mas*, membranous area of scutellum; *Mc*, mid coxa; *Pa*, pleural apophysis; *Pn*, postnotum; *Pp*, posterior phragma; *Prs*, prescutum; *Psms*, pleural sclerite of mesothorax; *Psmt*, pleural sclerite of metathorax; *Pspr*, pleural sclerite of prothorax; *Pwp*, prealar wing process; *Sc*, scutum; *Scm*, scutellum).

For convenience, the drawings are made partly diagrammatic. The names between brackets in the explanations of Figures 1,2 and 3 are those names used by Stickney, but here rejected for one reason or another as explained in the following discussion.

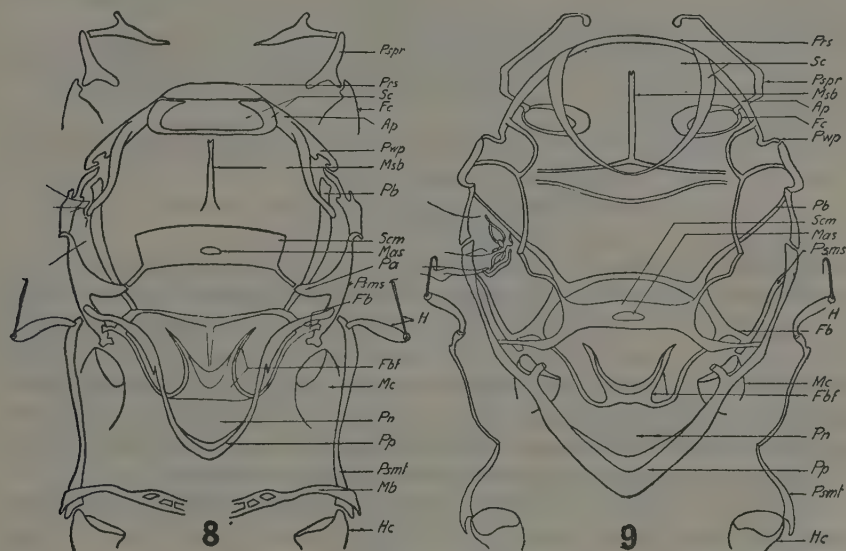


Fig. 8 : *Quadraspidiotus perniciosus* (Comst.), thorax of the adult male, dorsal view, $\times 140$. — Fig. 9 : *Lencaspis japonica* Ckll., thorax of the adult male, dorsal view, $\times 170$ (*Ap*, anterior phragma; *Fb*, furcal bridge; *Fbf*, furca and base of furca; *Fc*, fore coxa; *H*, haltere; *Hc*, hind coxa; *Mas*, membranous area of scutellum; *Mb*, metathoracic bridge; *Mc*, mid coxa; *Msb*, median sclerite of basisternum; *Pa*, pleural apophysis; *Pb*, pleural bridge; *Pn*, post-notum; *Pp*, posterior phragma; *Prs*, prescutum; *Psms*, pleural sclerite of mesothorax; *Psml*, pleural sclerite of metathorax; *Pspr*, pleural sclerite of prothorax; *Pwp*, prealar wing process; *Sc*, scutum; *Scm*, scutellum).

RESULTS AND DISCUSSION

The thoracic sclerotization of a coccid male depends largely upon presence or absence of wings. In the wingless forms the thoracic sclerites may be greatly reduced (Fig. 6), or even absent. Morrison described the wingless males of the genus *Stomaccoccus* Ferris [Margarodidae] as membranous throughout and the thorax as not enlarged or sclerotized; and McConnell reported the thorax of *Nipponaclerda biwakoensis* (Kuwana) [Aclerdidae] as entirely membranous without even indications of bars or sclerites.

On the other hand, the thoracic frame-work of winged forms resembles that of a typical pterygote thorax as herein represented by most of the figures.

The thoracic structure of the winged species under consideration generally agrees with that of *Parlatoria blanchardi* Targioni-Tozzetti, as described by Stickney. However, certain terms used by Stickney are here replaced by others, as follows :

1. For the sclerite below the prescutum, the term "anterior phragma" is used instead of "precosta" which is generally applied to the small first vein of the wing in certain fossil insects.

2. Since it is usual in winged Hemiptera to call the phragma-bearing tergite as "postnotum", this term is used here instead of "postscutellum" to indicate such tergite.

3. For easiness, "prescutum" is used instead of "praescutum" since both "pre" and "prae" indicate a preceding position.

4. The term "furcisternum" is replaced by "furcasternum" as long as it means a sternite related to the furca.

5. Stickney used the term "postcoxal bridge" for the sclerite connecting the base of furca with the pleuron. Meanwhile, he stated : "It may seem questionable to call this bridge "postcoxal" when it is situated cephalad of the coxa". However, the coxa has been drawn noticeably caudad, and in consequence has thrown the neighbouring parts out of their usual alignment. But the present study shows that the position of this bridge appears to be normally in front of the coxa, and therefore called the "furcal bridge" considering its proper position as well as its connection with the furca.

6. Since the term "postcoxal bridge" is rejected as above explained, the term "precoxal bridge" should also be changed to "pleural bridge" which sounds, in the same time, more indicative.

7. According to commonness, the term "pleural apophysis" is here used in the place of "prominent apodeme".

Aside from being winged or wingless, the coccid males may be classified according to other various thoracic features. The illustrations of the winged forms here studied demonstrate how easily they can be differentiated by the appearance of many thoracic sclerites in spite of the fundamental similarity in structure. Some of the differentiating characters are more obvious than others and thought to be a good subject for further study on coccid taxonomy. In the following points, special notes are listed about the most promising characters.

1. Halteres: The winged *Aclerda* spec. (Fig. 7) and *Pulvinaria ericicola* (Fig. 1) are characterized by the apparent absence of halteres, which in the same time has affected the size of the pleural sclerites of metathorax.

2. Median sclerite of basisternum: It is rather striking to find this sclerite prominent only in the two members of Diaspidinae (Figs. 8 and 9).

3. Metathoracic bridge: It is interesting to note that this

bridge, though well developed in *Q. perniciosus* [Aspidiotini] (Fig. 8), is absent in *L. japonica* [Diaspidini] (Fig. 9), whereas both tribes belong to the same subfamily.

4. Scutum: This tergite assumes a particular form for each of the studied species.

5. Membranous area of scutellum: This area appears to be comparatively large in *P. ericicola* (Fig. 1), very small in *Q. perniciosus* (Fig. 8), and having a conspicuous appearance in *P. vitis* (Fig. 4).

6. Sclerotized connection between the scutum and the scutellum: Such connection is obviously direct in the case of *P. ericicola* (Fig. 1) only.

SUMMARY

This paper represents a study of the thoracic sclerotization of the adult male in six coccid species belonging to four different families of Coccoidea. Meanwhile, some of Stickney's terminology in this aspect are replaced by others.

The study has thrown light upon certain thoracic characters as promising in coccid taxonomy, such as: the shape of the scutum and the membranous area of scutellum; and the presence or absence of the wings the halteres, the median sclerite of basisternum, the metathoracic bridge, and the sclerotized direct connection between scutum and scutellum.

REFERENCES

- McConnell, H.S. (1953): A classification of the coccid family Acleridae (Tech. Bull. A-75, University of Maryland Agriculture Experiment Station, pp. 17-22).
- Morrison, H. (1928): A classification of the higher groups and genera of the coccid family Margarodidae (Tech. Bull. No. 52, U.S. Dept. Agric., pp. 27 and 60).
- Snodgrass, R. E. : Principles of insect morphology (Text-book, pp. 157-192).
- Stickney, F. S. (1934): The external anatomy of the parlatoria date scale, *Parlatoria blanchardi* Targioni-Tozzetti, with studies of the head skeleton and associated parts (Tech. Bull. No. 421, U.S. Dept. Agric., pp. 41-48).

Biological studies on the furniture cockroach *Supella supellectilium* Serv., in Egypt

[Orthoptera : Blattidae]

(with 8 Text-Figures, and 7 Tables)

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I. INTRODUCTORY AND HISTORICAL

Cockroaches are house-dwelling pests in many parts of the world. In addition to the troubles they cause to inhabitants, they also spoil and consume goods and food. The characteristic nauseating odour left by these insects on food is not easily got rid of even after cooking. Recent medical researches revealed that cockroaches can transmit the causative organisms of some diseases and are possible intermediate hosts of some parasitic Nematodes.

Five species of cockroaches are common in Egypt, these are *Periplaneta americana* L., *Blattella germanica* L., *Supella supellectilium* Serv., *Blatta orientalis* L., and *Polyphaga aegyptiaca* L. With the exception of the last two species, they are frequent in our houses.

Most information on the biology of roaches is derived, uptill now, from work carried out in environments other than Egypt. For this reason, it was found advisable that a series of mainly biological and ecological studies on

Egyptian species of cockroaches be undertaken in the Department of Entomology, Faculty of Science, University of Cairo. The present work deals with the biology of one of these species, *Supella supellectilium*, and constitutes the first step towards the execution of the whole project. The results arrived at were, as far as possible, compared with those of other workers on other common species of cockroaches.

A review of the literature reveals that the biology of cockroaches has been previously studied by several workers. Among these, Marlatt (1917), Sein (1923), von Fischer (1927), Nigam (1933), Gould and Deay (1938), Rau (1940), Griffiths and Tauber (1942), and Gupta (1947), directed more attention to *Periplaneta americana* L. On the other hand, *Blattella germanica* L. was studied by Wille (1920), Ross (1929), Seamans and Woodruff (1939), Pettit (1940), and Khalifa (1950); while *Blatta orientalis* L. was studied by Rau (1924), Zabinski (1929 and 1933), and Qadri (1938). Other less common species of cockroaches were little dealt with, e.g. *Procoblatta pennsylvanica* De Geer (Rau, 1940) and *Periplaneta fuliginosa* Serv. (Rau, 1945). Laing (1946) gave a general account of the bionomics of *Blatta*, *Blattella*, *Periplaneta americana* L. and *P. australasiae* F. More recently, Roth and Willis (1952) studied the sexual behaviour of *Blattella*, *Blatta* and *Periplaneta* in some detail.

With the exception of Cottam (1922) and Gould and Deay (1940), no workers gave valuable information on the biology of *Supella supellectilium*. Cottam reared some specimens in Khartoum and gave some data on the longevity, oviposition, incubation period and nymphal duration of "*Blattella*" *supellectilium* under room conditions. Gould and Deay, on the other hand, gave more data on the biology of *Supella* and compared them with those on the five species of cockroaches that inhabit buildings in Indiana, i.e. *Blattella germanica*, *Blatta orientalis*, *Procoblatta pennsylvanica*, *Periplaneta americana* and *P. fuliginosa*.

II. GEOGRAPHICAL DISTRIBUTION

Since 1839 when *Supella supellectilium* was first recorded by Serville from houses in Paris, it is noticed that this species has become universally established and almost met with in many ecologically different parts of the world. *Supella* was included among the list of the cosmopolitan species in Wytzman Genera Insectorum (1908). Whelan (1929) suggested that this species may have found its way to America from the West Indies by means of commerce. Back (1937) has drawn the attention to the increasing importance of *Supella* and gave a list of the territories of its distribution in the United States. Chopard (1935) pointed out that the distribution of *Supella* in the African continent is less artificial, i.e. less influenced by man

than it is elsewhere and consequently it seems to be originally an African insect. More recently Chopard (1943) stated that this cosmopolitan species is on its way to temperate zones.

The following distribution records of *Supella* are also to be found in the literature: Egypt: Thebes, Helwan, Berket Karoun and other localities along the Nile Valley from Shellal to Wadi Halfa (Werner, 1905, and Innes Bey, 1912).—Sudan: Khartoum (Cottam, 1915-1922).—British Islands (Shelford, 1908 and 1911).—Queensland; Australia (Shaw, 1924).—The French Empire: North Africa and Hoggar (Chopard, 1929, 1941, and 1943).—North America (Whelan, 1929; Back, 1937; Lawrence, 1938; Severin, 1939; Flock, 1941; and Knowlton, 1942).—Mexico; Central America (Hebard, 1917).—Brazil; South America (Rehn, 1916).—Honolulu; Hawaiian Islands (Zimmerman, 1943).—Suva, Fiji (Lever, 1943).

III. MEDICAL IMPORTANCE AND NATURAL ENEMIES

Like other cockroaches, *Supella supellectilium* is an omnivorous insect eating nearly all kinds of food as well as its own faeces and occasionally regurgitating its gut contents. By this way various kinds of pathogenic bacteria and viruses could be transmitted to man.

A review of the more recent work on the medical importance of cockroaches reveals that *Supella* can transmit salmonellosis, a disease associated with stomach poisoning. In 1948, during an epidemic of salmonellosis in Brisbane, Mackerras and Pope detected four species of the bacillus *Salmonella* in the faeces of *Supella* and suggested that other species of cockroaches may have a considerable capacity to spread the disease as well. Later on, this suggestion was confirmed by Olson and Ruegar (1950) who found that the bacilli of *Salmonella* were ingested and excreted by *Periplaneta*, *Blatta* and *Blattella*. These authors have found that the bacilli can survive in the faecal pellets of the three species for several months.

Supella supellectilium was found to be parasitized by *Anastatus blattidarum* Ferr. in Arizona. According to Flock (1941), this hymenopterous parasite, which was previously described from Khartoum, was found in association with *Supella* in the buildings of Lancaster, especially in the warm season. The parasite deposits its eggs inside the egg-capsule of the cockroach where the larvae of *Anastatus* hatch and feed and can be found as dirty coloured maggot-like creatures. The fully formed parasites emerge through a tiny hole and as many as 16 adults may come out of a single egg-capsule. The author stated that *Anastatus* is a specific parasite of *Supella* and that it did not attack other species of cockroaches as *Periplaneta* and *Blattella*. In Egypt, *Anastatus tenuipes* Bol. y Peltain has been bred by Mr. A. Alfieri from an ootheca of

Supella supellectilium. This Eupelmid hymenopteron, which was described by Bolivar y Peltain (1925), is actually often found in houses in Cairo.

Another egg-parasite of *Supella* is *Comperia fulvicornis* Gomes, an Encyrtid recorded from Honolulu by Zimmerman (1943). According to this author, more than 20 adults of this hymenopterous species were reared from a single egg-capsule. *Comperia fulvicornis* seems also to attack the egg-capsule of *Blattella germanica* in Brazil (Gomes, 1942).

IV. MATERIAL, METHODS AND TECHNIQUE

For the study of the biology of *Supella supellectilium*, a stock of cockroaches was kept in glass battery jars of 500 cc. capacity. Sufficient food consisting of bread crumps, orange marmalade and dried milk was regularly supplied. The mouths of the jars were smeared with vaseline and covered with suitable pieces of organdie held tightly by means of rubber bands. Glass vials (6×12 cm.) were prepared for studying the biology of the adults. In each vial, a newly moulted female and male were isolated and supplied with sufficient food and water, which were changed every other day. Corrugated cardboard paper was placed in each vial in order to provide the insects with a more or less natural habitat. The egg-capsules were removed as soon as they were deposited and then transferred to small sample tubes 2.5 × 6 cm. each. The newly hatched nymphs were isolated each in a separate glass tube containing food and corrugated paper. All the vials and glass tubes were given serial numbers.

Two series of experiments were conducted: the first under room conditions and the second under controlled conditions. In both series observations were made daily. Oviposition was credited to the day on which the mother released the egg-capsule, while the moult to the day on which the exuvium was first observed. If the latter was not detected, the pale colour and inflated abdomen of the nymph were taken as indications of moulting. A hygrothermograph couple was utilized to record the room temperature and relative humidity. In the controlled experiments three temperatures were used; these were 25, 30 and 32°C. For lack of equipment, it was not possible to test the effect of temperature at other degrees. In the relative humidity experiments, different concentrations of analar sulphuric acid solution were made to produce different relative humidities (Buxton and Mellanby, 1934). The specific gravities of the resulting solutions were measured by the aid of the Gallenkamp's specific gravity hydrometers. The relative humidities produced by the various acid concentrations were checked before use by means of Edney's paper hygrometer. About 250 cc. of the solution were placed at the bottom of a glass museum jar in which the experiment was

to be conducted. A wire gauze false floor resting on glass bridges was used to separate the insects from the acid solution. The jars were tightly covered with glass lids. Five relative humidities, ranging from 40 to 80%, were used. It was difficult to control humidity below or above this range, as in the first case the insects could not withstand drought for sufficient periods, while in the second case accumulation of moulds caused a great injury to them.

The egg-capsules were examined in small watch glasses under a binocular microscope. Permanent preparations of the cast skins and of the first to the third nymphal instars were made. The succeeding nymphal instars were mounted and preserved. All drawings were made by the aid of the camera lucida.

The results obtained from all experiments were statistically analysed according to the method of C.B. Williams (1937) in which logarithms were used to obtain geometric means instead of the usual arithmetic means. Fischer and Yates statistical tables were used to test the significance of the data obtained.

The biological observations and experiments carried out in the course of the present work continued for about three years (1950-1953).

V. BIOLOGY

Cottam (1922) reared several females in Khartoum. He pointed out that "*Blattella*" *supellectilium* (the name used by the author to designate *Supella supellectilium*) breeds throughout the year, and that the female may live up to 76 days. After an average pre-oviposition period of about 13.7 days, she deposits from five to twelve egg-capsules at average intervals of about 6.2 days. The eggs require an average period of about 35 days to hatch, and the nymphs reach maturity within 103 days during late winter and spring, and 75 days during summer. No data were given by this author on the biology of *Supella* under controlled conditions.

The work of Gould and Deay (1940) on the biology of the six species of cockroaches that inhabit buildings in Indiana, contained valuable information on the biology of *Supella* under room and controlled conditions. These workers, however, did not give sufficient attention to such points as the post-oviposition period, the sexual behaviour, the hatching mechanism, moulting, number and morphology of the nymphal instars. These points will be dealt with in more detail and will form the paramount feature of the present work.

Supella supellectilium is a recent house dweller of tropical origin. It is common in Egypt, where it is found all the year round, but not as abundant as the American and the German cockroaches. In certain seasons, however, i.e. spring and summer, it exhibits itself in greater numbers. It is also met with

in the beginning of the autumn, but mostly in the form of nymphs. In winter, it is rarely found.

THE ADULT STAGE

1. Habits and habitat

The adult *Supella* wanders in nearly all rooms of the house and only visits the kitchen when searching for food. It hides in cupboards, pantries, closets, fruit-stands, book-shelves, drawers, and behind picture frames, etc. It loves darkness and in its natural habitat it is disturbed when the lights are suddenly turned on.

Like the German cockroach, *Supella* is very active. In an attempt to catch a male, it ran so swiftly in a winding movement that it was difficult to capture it. The male is a good runner and can also fly for short distances. The female is less active and unable to fly.

Although *Supella* is an omnivorous insect, yet it is especially fond of sweet material. It was often seen indulged in a slice of bread covered with a smear of jam. Dry food does not attract it very much and it usually misses a piece of sugar unless it is wet. On the other hand, it was attracted to a wet piece of cotton wool.

When the food is sufficiently damp, the individuals aggregate around it and stand on their hind legs raising their heads and working their mandibles and maxillae in swift movements. During feeding, the antennae move too.

Supella most probably seeks for its food by smell since it is more strongly attracted to flavoured and scented food, e.g. marmalades, bananas or cinnamon; while molasses and pure sugary and starchy material are not so attractive.

The insect can withstand starvation for considerable periods on condition that water is provided. Specimens were collected at the same date and each sex separated in a jar containing little water in a micro-tube. The males survived for a maximum period of twelve days and the females for three weeks.

2. Longevity

To study the longevity of the adult, two series of experiments were conducted: the first under room conditions and the second under controlled conditions.

Under room conditions the longevity of both sexes differed according to seasons. Forty males and forty females were kept under observation during the cold season, i.e. from October to February (15-21°C. and 50-70% R.H.). The longevity of the female ranged between 165 and 210 days,

with an average of about 183.8 days. That of the male ranged between 131 and 178 days, the average being about 152.2 days. Using the same number of males and females, from May to August (26 to 35°C. and 40-65% R.H.), the longevity of both sexes was distinctly shorter. The female lived for an average period of about 115.8 days while the male for about 95.3 days.

In the second series of experiments, temperature and relative humidity were kept constant at 32°C. and 70% R.H., respectively. Under these conditions which proved more favourable, the female lived from 80 to 128 days, with an average longevity of 104.4 ± 3.2 days. In the case of the male, the longevity ranged between 70 and 100 days; the average being 86.5 ± 2.5 days (Table I).

To test the effect of temperature on longevity, the relative humidity was kept constant at 70% and two other series of experiments were carried out at 30 and 25°C. At 30°C. the longevity of both sexes was slightly affected, the average being 109.5 ± 4.4 in the female and 90.2 ± 2.8 in the male. At 25°C., however, the longevity was considerably prolonged in both sexes. In the female it ranged between 105 and 170 days (average 135.8 ± 5.5), while in the male it was from 86 to 140 days; the average being 114.9 ± 4.1 (Table I).

TABLE I

The longevity of the adult at different temperatures and humidities

			32 °C.					70% R. H.		
			40%	50%	60%	70%	80%	25°C.	30°C.	32°C.
LENGTH OF ADULT LIFE IN DAYS	FEMALE	Minimum	99	95	93	87	90	105	90	80
		Maximum	138	138	130	120	128	170	130	128
		Average	118	115	113.9	103.6	109	135.8	109.5	104.4
			± 4.3	± 4.2	± 3.8	± 2.0	± 3.6	± 5.5	± 4.4	± 3.2
	MALE	Minimum	85	80	77	70	73	86	70	70
		Maximum	113	106	103	93	101	140	110	100
		Average	99.7	93.8	90.1	81.2	88.2	114.9	90.2	86.5
			± 2.1	± 1.8	± 1.9	± 1.2	± 1.6	± 4.1	± 2.8	± 2.5

From these data it may be concluded that below 30°C. (R.H. 70%) temperature is a highly significant factor in relation to longevity. A decrease of 5°C. below 30 increased the longevity by an average period of 26.3 days in the female and 24.7 days in the male.

To test the effect of humidity on longevity, temperature was kept constant at 32°C., and a series of experiments was conducted at 40, 50, 60, 70, and 80% R.H. It was difficult to control the relative humidity below 40% or above 80%, as in the former case the individuals could not withstand drought for sufficient periods, and in the latter case accumulation of mould on the food caused a great injury to them.

The average longevity of both sexes at the different grades of relative humidities is given in Table I. From the results obtained it seems that humidity, under the given experimental conditions, has no pronounced effect on the longevity of both sexes. This, however, is shortest at 70 and longest at 40% R.H.

3. Mating and sexual behaviour

Males showed tendency to copulate with females three to five days after maturity. An excited male is distinguished by its stretched abdomen and slightly protruded genitalia. The female shows no indication of her desire for the sexual act.

When a male and a female are gathered in a sufficiently dark place, the former tries the latter with his antennae. The two individuals then face one another and stroke each others' antennae. After a short time (not exceeding one minute) the male turns around raising his wings and exposing his terminalia in the direction of the female. The latter begins to work her mouth parts on the male's seventh abdominal tergum. In this pose the male lies beneath the female with his cerci erect touching her thorax. This is the female superior pose (Roth and Willis, 1952) or the vertical pose (Lamb, 1922), and it lasts for a few seconds. Immediately the male twists his abdomen moving away from under the female. The two sexes become then joined by their genitalia with their heads in opposite directions and the false linear position is thus attained. In this position the female rests her hind legs against the pleura of the male's abdomen. The false linear position lasts for at least one hour. The total time necessary to complete the sexual act varied from 65 to 100 minutes, with an average of about 80 minutes.

Roth and Willis (1952) studied the process of mating in several species of cockroaches. The average periods recorded by these authors were 86 minutes in *Blattella*, 70 in *Periplaneta* and 30 in *Blatta*. Khalifa (1950), working on *Blattella germanica*, has pointed out that the male and the female may remain in copula for two or three hours.

In *Supella* copulation may occur once or twice a day. After the first copulation, the male was removed, and the female produced the normal number of egg-capsules.

Parthenogenetic reproduction was not observed in this species. Several unmated females deposited a small number of egg-capsules (from two to four each). Some of these capsules shrivelled within two weeks. The other capsules remained unchanged for about three months and when finally examined they were found to be dry and empty.

4. Oviposition and fecundity

a. The pre-oviposition period

Under room conditions, the pre-oviposition period varies considerably according to seasons. For instance, in May (26-31°C. and 40-60% R.H.) it varied in the range of 14 to 19 days with an average of about 16.1 days. In October on the other hand (19-21°C. and 50-60% R.H.), the pre-oviposition period was markedly prolonged and ranged between 20 and 35 days; the average being about 28.3 days.

When compared with other cockroaches, it seems that *Supella* has a relatively longer pre-oviposition period. According to Gould and Deay (1940), the pre-oviposition period of *Supella*, *Blatta*, *Blattella* and *Periplaneta* is about 21.3, 19, 16.6 and 13.7 days, respectively (average room temperature 75°F. or about 24°C.).

The pre-oviposition period of *Supella* became distinctly shorter, however, in a sufficiently damp warm atmosphere. Thus, at a constant temperature of 32°C. and relative humidity of 70%, the average pre-oviposition period was 13.2 ± 0.5 days (Table II).

TABLE II

The pre-oviposition period, number of egg-capsules per female, period between egg-capsules and post-oviposition period at different temperatures.

(Relative humidity 70%)

TEMPERATURE IN °C.	PRE-OVIPOSITION PERIOD IN DAYS			NUMBER OF EGG-CAPSULES PER FEMALE			PERIOD BETWEEN EGG-CAPSULES IN DAYS			POST-OVIPOSITION PERIOD IN DAYS		
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
25	17	27	21.8 ± 0.6	5	12	8.5 ± 0.6	9	16	12.7 ± 0.5	10	19	14.5 ± 0.45
30	11	17	14.0 ± 0.4	8	18	13.3 ± 1.0	6	10	7.9 ± 0.6	4	6	4.8 ± 0.5
32	10	18	13.2 ± 0.5	8	20	14.4 ± 0.4	5	9	6.8 ± 0.7	4	5	4.7 ± 0.4

When the temperature was lowered to 30°C., no difference in the average period was practically observed. On the other hand, when the temperature was further lowered to 25°C., the pre-oviposition period was considerably prolonged, reaching an average of 21.8 ± 0.6 days (Table II).

The influence of humidity on the pre-oviposition period was tested in a series of experiments in which five relative humidities ranging from 40 to 80% were used, temperature being kept constant at 32°C. It was found

that: (a) the average pre-oviposition period was shortest (13.2 days) at 70% R.H. and longest (23.8 days) at 40% R.H.; (b) the effect of relative humidity on the pre-oviposition period was more pronounced below 50% R.H. and rather slight above it (Table III).

TABLE III

The pre-oviposition period, number of egg-capsules, period between egg-capsules and post-oviposition period under the different humidities.

(Temperature 32°C.)

PERCENTAGE RELATIVE HUMIDITY	PRE-OVIPOSITION PERIOD IN DAYS			NUMBER OF EGG-CAPSULES PER FEMALE			PERIOD BETWEEN EGG-CAPSULES IN DAYS			POST-OVIPOSITION PERIOD IN DAYS		
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
40	19	30	23.8 ±0.6	3	6	4.2 ±0.3	18	27	22.4 ±0.55	12	21	16.4 ±0.6
50	14	20	16.4 ±0.4	4	8	6.4 ±0.25	12	18	14.2 ±0.45	10	15	12.5 ±0.25
60	13	19	15.8 ±0.4	6	11	8.7 ±0.25	7	15	10.7 ±0.3	6	12	9.1 ±0.4
70	12	14	13.2 ±0.2	8	19	14.7 ±0.35	4	9	6.2 ±0.3	4	5	4.5 ±0.25
80	12	18	14.2 ±0.3	6	13	11 ±0.3	6	11	8.6 ±0.3	6	10	8.1 ±0.3

From the results of the foregoing experiments it seems that 70% R.H. and 30 to 32°C. are more favourable conditions below and above which the pre-oviposition period is prolonged. It is also clear that in the range of 40 to 50% R.H. and 25 to 30°C., humidity and temperature, respectively, seem to have a highly significant effect on the pre-oviposition period.

b. Habits of the female during oviposition

The female remains still and inactive for one or two days before the appearance of the egg-capsule. Probably this is the period necessary for the arrangement of ova in rows and the formation of the capsule around them. After this period, the fully formed egg-capsule protrudes very slowly from the genital pouch, being held tightly and protected by the stretched gynovalvar membrane. In the beginning, the egg-capsule is pale yellow but it gradually becomes darker by exposure to air.

The egg-capsule is carried by the female with its seam upwards. It remains in this position for a period ranging between twenty-four and fifty hours, but when it is cold this period may be prolonged to several days.

When going to oviposit the female seems anxious, searching for a suitable situation. In the rearing jars she prefers the folds of the cardboard paper and, if not present, she oviposits on the cloth covering the mouth of the jar. Once the suitable substratum is found, the female applies her head to it, working her mouth parts for a few seconds after which the surface becomes covered with a gummy secretion. The female then turns around, stretches her hind legs apart, grasping the surface with the tarsi. She then bends her abdomen till it touches the substratum, and by the alternate telescoping and stretching of her terminalia the egg-capsule is finally deposited. The whole process is completed in about 4 to 10 minutes. The deposited egg-capsule remains exposed and the developing young are left to the care of chance.

In some other species, more care is shown by the mother during oviposition, and the egg capsules, after being deposited, are usually covered with a protective layer of clay, plaster, debris or saw dust, and hence not easily detected. R a u (1943) observed the female *Periplaneta americana* while excavating a hole in a rotten piece of wood and carefully sweeping it with her mouth parts. He also watched another female secreting the adhesive substance for twelve minutes. After depositing the egg-capsule in the hole, he watched the mother picking it up again with her mandibles and re-embedding it carefully. She then covered it with another layer of secretion and finally plugged the hole with saw dust. The same author observed the female *Blatta orientalis* removing her egg-capsule from the hole and running her mandibles over the serrated edge as if knitting and cementing it.

The female *Blattella germanica* does not release the egg-capsule before the young are fully developed, and then she deposits it wherever she happens to be (Pettit, 1940). Sometimes the egg-capsule may be retained by the female until hatching is complete (L a i n g, 1946).

c. The rate of oviposition

Under room conditions, the total number of egg-capsules deposited by a single female differed according to seasons. From May to August (26-35°C. and 40-65% R.H.) the number of egg-capsules deposited per female varied from eight to twenty (average 13.17). From October to February (15-21°C. and 50-70% R.H.) the number dropped considerably to three or at most eight egg-capsules (average 6.1). In one of the observations the maximum number of egg-capsules was ten.

According to Gould and Deay (1940) the average number of capsules deposited per female was 13 in *Supella*, 5 in *Blattella*, 9 in *Blatta* and 53 in *Periplaneta* (average room temperature 75°F., i.e. about 24°C.).

Under controlled conditions (32°C. and 70% R.H.) the total number of egg-capsules deposited per female *Supella* varied from 8 to 20 with an average

of 14.4 (Table II). When the temperature was lowered to 30°C. (relative humidity kept constant at 70%), no marked change in the number of capsules was observed. On the other hand, when the temperature was lowered to 25°C., an appreciable reduction in the number of capsules became obvious (Table II).

Humidity also seems to be an important factor influencing the rate of oviposition. At 40% R.H., temperature being kept constant at 32°C., the average number of capsules deposited per female was as low as 4.2. When the relative humidity was progressively raised to 70%, the average number gradually increased. The increase became more marked from 60 to 70% R.H. At higher relative humidities (e.g. 80%) an obvious fall was recorded (Table III).

From the results of these experiments it seems that the maximum number of egg-capsules deposited per female is reached at 70% R.H. and 30 or 32°C.

d. *The periodicity of depositing egg-capsules*

During the summer (from May to August), the period elapsing between two successively deposited egg-capsules ranged between 5 and 9 days with an average of 6.98. During the autumn and winter however (from October to February), this period was considerably prolonged and ranged between 10 and 22 days (average 15.64 days).

Under controlled conditions (32°C. and 70% R.H.) the average period between capsules was 6.8 days. When the temperature was lowered to 32°C. (relative humidity kept constant at 70%), the average period between capsules slightly increased. By a further lowering of temperature to 25°C., this period was markedly prolonged to an average of 12.7 days (Table II).

Humidity, like temperature, seems to influence the periodicity of capsules. The shortest period between the deposition of capsules (6.2 days) was reached at 70% R.H., and the longest (22.4 days) at 40% R.H.. Above 70% (e.g. at 80% R.H.) a slight increase was observed. Below 70% on the other hand, the period increased steadily and the increase became more pronounced and nearly twice as much from 50 to 40% (Table III).

When compared with other species, it was found that the average period between egg-capsules in *Supella* is longer than in *Blatta* and *Periplaneta*, while it is considerably shorter than in *Blattella*. At a uniform room temperature (average 70°F. or about 21°C.), the average period between egg-capsules was 13.7 days in *Supella*, 9.1 in *Blatta*, 6.1 in *Periplaneta*, and 40.3 in *Blattella* (Gould and Deay, 1940).

e. *The post-oviposition period*

This is the period during which the female lives after depositing the last

egg-capsule. Under favourable conditions (warmth, humidity and regular food supply) the female continues oviposition until the last four or six days of her life. Under unfavourable conditions (cold, dryness and scarcity of food) the female ceases oviposition 19 to 28 days before her death. It was observed that during the cold season in February, the post-oviposition period was nearly five times longer than what it was during the warm season in August.

Under controlled conditions (32°C. and 70% R.H.) the average post-oviposition period was almost equal to what it was in August (4.7 days). When the temperature was lowered to 30°C., no pronounced effect was observed. On the other hand when the temperature was further lowered to 25°C., the post-oviposition period became about three times longer (Table II).

In testing the possible effect of humidity on the post-oviposition period it was found that, when the relative humidity was progressively lowered from 70 to 40% (temperature kept constant at 32°C.), a gradual prolongation in the post-oviposition period was observed (Table III). Above 70% R.H. (e.g. at 80%) the post-oviposition period increased again.

Judging from the foregoing results, the post-oviposition period is shortest at 30 or 32°C. and 70% R.H., and the female under such conditions seems to remain fertile for the longest period of her life.

VII. THE EGG-STAGE

1. Description of the egg and egg-capsule

The fully formed egg-capsule (Fig. 1) is a small purse-shaped reddish brown structure. It is the smallest of the egg-capsules of the more common cockroaches, its basal margin being about 4 mm. in length and its height slightly exceeding 2.5 mm. The upper margin of the capsule is in the form of a serrated crest called the seam (Fig. 1, A, S), slightly longer than the lower margin. The seam bears 18 or 19 teeth which correspond roughly to the number of eggs included. The capsule is slightly concave at the base and its anterior and posterior edges are rotundate.

On either side, the capsule exhibits nine vertical furrows extending between the base and the seam and indicating the boundaries between the eggs. The furrows of one side are alternate in position with those of the other side and meet them across the upper margin in a zig-zag manner (Fig. 1, B). The line where they meet is somewhat extended as a faint suture along the anterior and posterior edges of the egg-capsule, indicating its line of dehiscence (Fig. 1, C, L.D).

On either side, the furrows enclose between them slightly convex bands, which are interlocked with those of the other side along the upper margin. These bands (Fig. 1, B,P.E) indicate the position of the eggs.

The usual number of eggs in a capsule is eighteen, eight on either side,

one at the anterior and one at the posterior extremity. The eggs (Fig. 1, A, E) are more or less crescentic in shape and yellowish white in colour. They are arranged vertically within the egg-capsule with their straight edges facing one another.

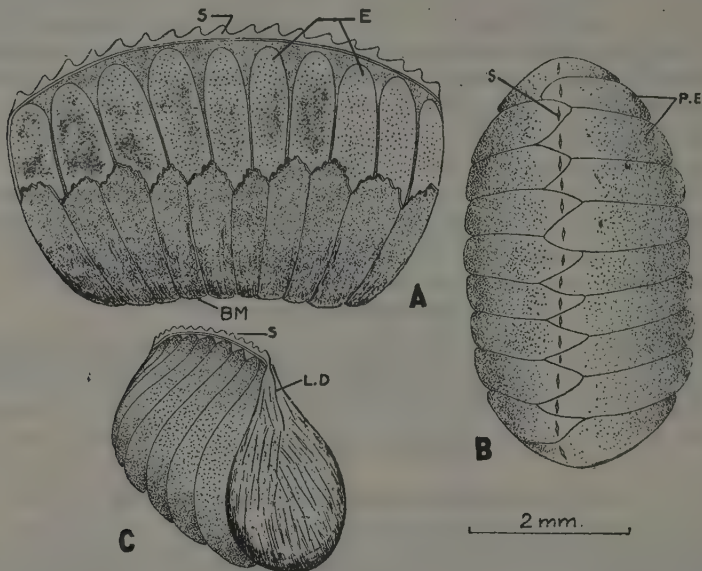


Fig. 1 : Egg-capsule of *Supella supellectilium* Serv. : (A) lateral view, (B) upper view, (C) frontal view (BM, basal margin ; E, eggs ; L.D, line of dehiscence ; P.E, position of eggs ; S, seam).

A few days before maturity the compound eyes of the embryo become visible through the transparent shell as two minute dark dots. A greenish spot appears near the middle, probably due to the accumulation of metabolic products in the alimentary canal of the embryo (Woodruff, 1938). The dark dots and greenish spots are also visible through the walls of the mature capsule and may be taken as an indication of the date of hatching.

2. The incubation period

The embryos of *Supella* require a relatively long period for their development. Under room conditions the incubation period varied considerably according to seasons. From January to April (16-29°C. and 50-65% R.H.) the time required for hatching ranged between 80 and 97 days with an average of about 89 days. In June and July however (26-31°C. and 40-60% R.H.),

this period was considerably shorter, ranging between 33 and 42 days, with an average of about 38 days,

At a constant temperature of 32°C. and relative humidity of 60%, the average incubation period was about 33.2 days (Table IV). When the temperature was lowered to 30°C., this average increased to about 37.5 days and when the temperature was further lowered to 25°C. the average became nearly twice as much.

TABLE IV

The incubation period, number of hatching nymphs per egg-capsule, and percentage of egg-capsules yielding the maximum number of nymphs at different temperatures.

(Relative humidity 60%).

TEMPERATURE IN °C.	INCUBATION PERIOD IN DAYS			NUMBER OF HATCHING NYMPHS PER EGG-CAPSULE			PERCENTAGE OF EGG-CAPSULES YIELDING THE MAXIMUM NUM- BER OF NYMPHS
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	
25	69	83	73.3 ± 1.1	9	16	13.3 ± 0.7	11.6
30	33	43	37.6 ± 0.8	12	16	14.1 ± 0.6	19.8
32	32	39	33.2 ± 0.6	12	16	14.7 ± 0.6	23.7

TABLE V

The incubation period, number of hatching nymphs per egg-capsule, and percentage of egg-capsules yielding the maximum number of nymphs at different humidities.

(Temperature 32°C.)

PERCENTAGE RELATIVE HUMIDITY	INCUBATION PERIOD IN DAYS			NUMBER OF HATCHING NYMPHS PER EGG-CAPSULE			PERCENTAGE OF EGG-CAPSULES YIELDING THE MAXIMUM NUM- BER OF NYMPHS
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	
40	41	61	50.2 ± 1.3	10	16	12.1 ± 0.5	7.9
50	34	46	40.7 ± 0.7	11	16	13.9 ± 0.5	11.6
60	32	39	33.7 ± 0.5	12	15	14.9 ± 0.3	24.1
65	32	36	35.0 ± 0.7	12	16	14.8 ± 0.5	20.2
70	39	47	42.9 ± 0.7	11	16	13.4 ± 0.5	11.6

To test the possible effect of humidity on the incubation period, temperature was kept constant at 32°C., and five relative humidities ranging from 40 to 70% were used. It was found that the average incubation period was shortest (33.7 days) at 60% R.H., above and below which the period was prolonged. The prolongation was more marked from 50 to 40% at which the average period lasted 50.2 days (Table V)

When compared with the other common species of cockroaches, it was found that the incubation period is longest in *Supella*. The average incubation period at a constant temperature of 82°F. (about 27.5°C.) was 44 days in *Supella*, 37 in *Blatta*, 32 in *Periplaneta* and 24 in *Blattella* (Gould and Deay, 1940). From the results of their experiments, these workers have also concluded that the incubation period in *Supella* is more markedly influenced by temperature. It was calculated that for every 1°C. rise in temperature, the incubation period should be reduced by about 9 days in *Supella*, 5 in *Periplaneta* or *Blatta*, and 3 in *Blattella*.

3. The number of hatching nymphs

Under natural conditions, the number of hatching nymphs varied during the cold and warm seasons of the year, but did not exceed 16 per egg-capsule. From January to April (16-29°C. and 50-65% R.H.), the number of hatching nymphs per egg-capsule varied from 9 to 15 (average 12.3), and none of the egg-capsules kept under observation gave the maximum number of nymphs. From June to July (26-31°C. and 40-60% R.H.), the number of hatching nymphs per egg-capsule increased and ranged from 12 to 16 (average 14.9). About 24% of the egg-capsules kept under observation gave the maximum number of 16.

The same result of the summer experiments was practically obtained again under controlled conditions of 32°C. and 60% R.H. Changing the temperature from 32 to 30°C., and then to 25°C., seemed to have no effect on the number of hatching nymphs per egg-capsule; the maximum number being 16 in all cases and the differences between the averages were slight (Table IV). It was only the percentage of capsules yielding the maximum number of nymphs which varied at the different temperatures being about two times greater at 32 than at 25°C.

Humidity seems also to influence the percentage of egg-capsules from which the maximum number of nymphs hatch. From the results shown in Table V, it is clear that the percentage of egg-capsules yielding the maximum number of hatching nymphs is greatest (about 24%) at 60% R. H., and so is the average number of hatching nymphs per egg-capsule (14.9). The lowest figures, however, appear in both cases at 40% R.H. (Table V).

4. The hatching mechanism

In order to examine the process of hatching, a mature egg-capsule was carefully opened by dropping it from a little height with its seam downwards. By this process the egg-capsule split open along the line of dehiscence and the tops of the egg-shells were broken. Immediately the capsule was transferred to a watch glass and examined under a binocular microscope.

The young found their way out through the broken edges of the shells and then through the opened seam of the egg-capsule. This process was accomplished by swallowing minutes air bubbles which accumulated in the crop. The abdomen became thus dilated and the resulting pressure forced the young partially to the outside. Several young from the middle of the egg-capsule appeared first and were followed immediately by another group and finally the young in the corners emerged; a process which took about three minutes. As soon as the head of the young became visible it struggled to find its way out.

In the normal hatching, it seems that the pressure exerted by all the nymphs results in the opening of the egg-capsule along the seam (Gould and Deay, 1938). It is doubtful that the young can secrete a fluid which dissolves the substance binding the lips of the egg-capsule together (Shelford, 1912, and Laing, 1946). Shelford (1912) stated that the embryo of *Blatta* or *Periplaneta* is provided with a pair of frontal vesicles which, when dilated, force the egg-shell and the edge of the egg-capsule to rupture.

VIII. THE NYMPHAL STAGE

1. Habits and habitat of the nymphs

Like the adults, the nymphs are active and are fond of warmth which accelerates their growth considerably. In the normal habitat the nymphs hide in the corners of drawers, behind frames and similar situations. In the rearing jars they remained excited for a week or more during which they made trials to escape during their feeding time. After this period of excitement, however, they became quite and well acquainted with their new habitat. The smaller nymphs had the habit of aggregation in small group between the folds of the cardboard provided while the elder ones remained separate from one another.

Like their parents, the nymphs love humid food and when water is supplied and a favourable temperature is ensured they can withstand starvation for several days. On the other hand, when the food is dry or when humidity is below 50%, the nymphs die in less than three days, because of drought.

2. The nymphal duration

The nymphal duration differs in both sexes and in the different seasons. During the summer (26-36°C. and 50-75% R.H.), the duration required for the development of the female ranged between 109 and 130 days (average about 119.2 days); whereas during the autumn and winter (15-25°C. and 45-65% R.H.) it was distinctly longer and ranged between 215 and 245 days (average about 231.2 days). The male requires a shorter nymphal duration, this being, on average, about 109.1 days in summer and 212.3 in autumn and winter.

At a constant temperature of 32°C. and relative humidity of 65%, the average nymphal duration was 119.8 days in the female and 107.5 in the male. When the temperature was lowered to 30°C. the nymphal duration of both sexes was slightly shortened. Further lowering of temperature to 25°C., on the other hand, resulted in a considerable prolongation in the nymphal duration, the average reaching 195 days in the male and 205 in the female (Table VI).

From the above results, it seems that under natural and controlled conditions the male requires a somewhat shorter developmental period than the female. The average difference between the nymphal duration of both sexes reached a minimum (about 10 days) during the warm season and a maximum (about 19 days) during the cold season.

When compared with other species, it was found that *Supella* as well as *Blattella* have considerably shorter nymphal durations than *Periplaneta* and

TABLE VI

The nymphal duration, average period between moults, and percentage of extra-moults in both sexes at different temperatures.

(Relative humidity 65%)

		T E M P E R A T U R E								
		25°C.			30°C.			32°C.		
		MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
SEXES										
Nymphal duration in days	Male	185	200	195	94	106	100	99	113	107.5
	Female	190	220	205	107	125	114	115	126	119.8
	Both sexes	185	220	199 ±2	94	125	109 ±2	99	126	115.1 ±1.8
Average period between moults	Male			31.2			16.7			19.1
	Female			28.6			16.4			16.8
Percentage of extra-moults	Male			24						17
	Female			17						14

TABLE VII

The nymphal duration, average period between moults, and percentage of extra-moults in both sexes at different humidities).

(Temperature 30°C.)

PERCENTAGE RELATIVE HUMIDITY		NYMPHAL DURATION IN DAYS			AVERAGE PERIOD BETWEEN MOULTS		PERCENTAGE OF EXTRA-MOULTS	
		MALE	FEMALE	BOTH SEXES	MALE	FEMALE	MALE	FEMALE
50	Minimum	118	125	118	19.3	18.2	25	20
	Maximum	123	140	140				
	Average	120.3	131	127 ± 1.6				
60	Minimum	108	115	108	18.2	17.2	10	5
	Maximum	113	128	128				
	Average	110.7	121.4	117.0 ± 1.7				
65	Minimum	97	103	97	16.7	16		
	Maximum	102	120	120				
	Average	100.2	111.1	106 ± 1.8				
70	Minimum	100	105	100	17	16.5	5	
	Maximum	105	130	130				
	Average	102.9	115.8	109.6 ± 2.4				
75	Minimum	110	118	110	18.8	18	10	5
	Maximum	118	138	138				
	Average	114.9	126.9	121.2 ± 2.2				

Blatta. The average nymphal duration at a uniform temperature of about 82°F. (27.8°C.) was about 93 days in *Supella*, 90 in *Blattella*, 300 in *Blatta* and 425 in *Periplaneta* (Gould and Deay, 1940). Absolutely different values for the nymphal durations of *Blatta* and *Periplaneta* were however recorded by other workers, i.e. Rau (1924), Zabinski (1929), Qadri (1938), Griffiths and Tauber (1942), and Laing (1946).

It was also found that *Supella* resembles *Blattella* and *Blatta* in the fact that the male requires a shorter developmental period than the female (Ross, 1929; Qadri, 1938; and Gould and Deay, 1940). The opposite was observed in *Periplaneta* (Griffiths and Tauber, 1942).

The possible effect of humidity on the nymphal duration was also tested. It was found that the nymphal duration was shortest in both sexes at 65-70% R.H., below and above which it was distinctly longer (Table VII).

Judging from the results of the foregoing experiments, the shortest nymphal duration is reached at 65% R.H. and 30°C., conditions which seem more favourable for the nymphal development.

3. The nymphal development

The embryonic moult takes place immediately after hatching and leads

to the first nymphal instar. In this instar, the body is about 2.4 mm. long from the occiput to the tip of the epiproct, and the head about 0.8 mm. from the occiput to the tip of the clypeus (Fig. 2). The longitudinal axis of the head measures about one third of that of the body. The antennae are of the female type (post-pedicel long and slightly covered with setae). The three thoracic

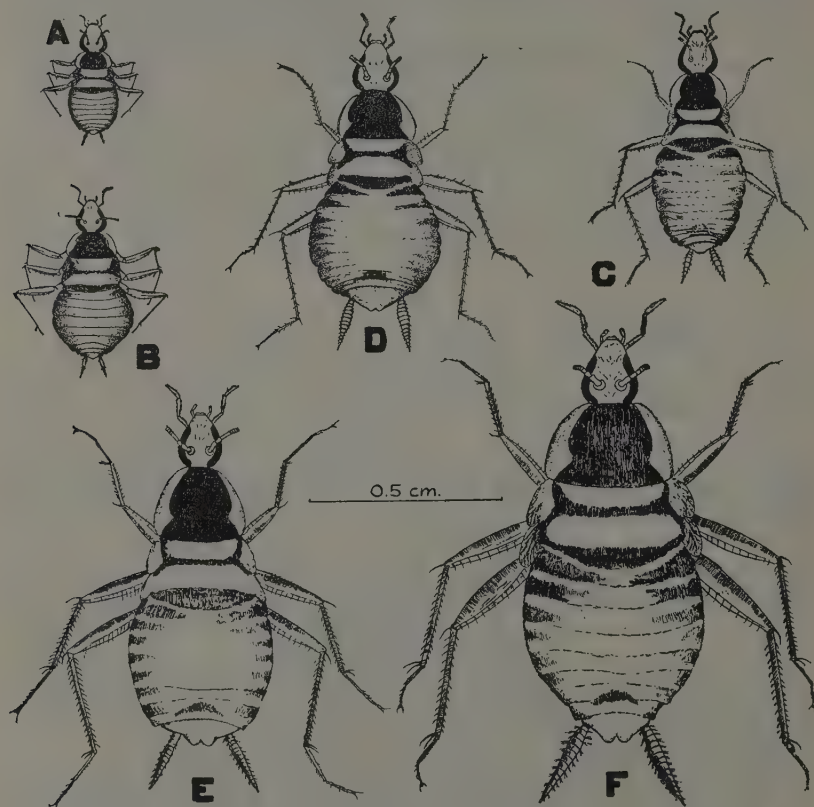


Fig. 2 (A - F) : The six nymphal instars of male *Supella supellectilium* Serv.

terga are well developed and the pronotal disc is trapezoidal in shape. The proportional length of the legs and leg segments is nearly the same as in the adult. There is no trace of wing-pads. The ten abdominal terga and sterna are distinct. The last tergum or epiproct is entire whereas the last sternum is completely divided into two halves (Fig. 3, A). The paraprocts are absent and the cerci are three-segmented, the median segment being the longest.

The two sexes are not distinguishable from one another in this stage, their ninth abdominal sternum being entire with a pair of one-segmented styli.

After about eight days, the first nymphal moult takes place leading to the second instar. In the latter (Fig. 2) the body is about 3.2 mm. long and the head about 0.9 mm. The pronotal disc is bell-shaped, thus resembling that of the adult. The ninth abdominal sternum (Fig. 3 B) is now notched and the cercus becomes four-segmented. Other parts of the body are like

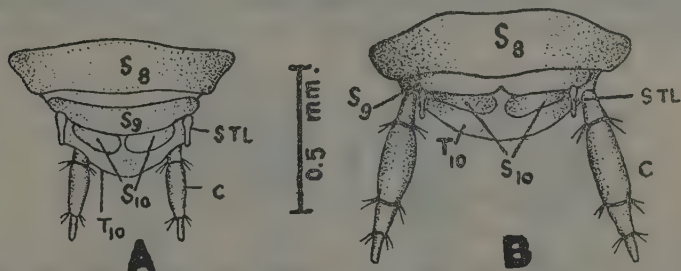


Fig. 3 : Ventral view of terminalia: (A) 1st. instar; (B) 2nd. instar. — (C, cercus; S8-S10, 8th. to 10th. sternum; STL, stylus; T10, last tergum or epiproct).

those of the first instar. The second instar lasts for about sixteen days after which another moult takes place leading to the following instar.

In the third nymphal instar (Fig. 2), the body is about 4.4 mm. long and the head about 1.1 mm.; the proportional length of the head thus decreasing to about one fourth of that of the body. The posterior margin of the metathoracic tergum becomes slightly arched. The eighth abdominal sternum undergoes a characteristic change in the female; it becomes divided into two lobes and slightly retracted beneath the seventh (Fig. 4). In both sexes the styli are present and the cercus is eight-segmented.

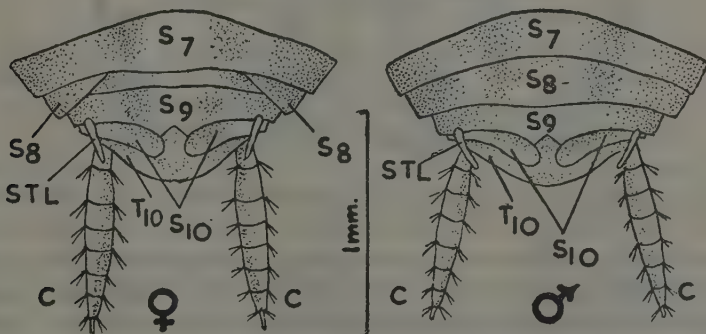


Fig. 4 : Ventral view of terminalia of third instar, male and female (S7, seventh abdominal sternum; other lettering as in Fig. 3).

After about twenty one days another moult takes place and the fourth instar is reached. In this instar (Fig. 2) the body is about 5.5 mm. long and the head about 1.2 mm. The wing pads begin to appear more obviously in the metathorax. The epiproct becomes notched in both sexes. In the male the eighth and ninth sterna remain unchanged, while in the female the eighth sternum becomes completely hidden and the ninth becomes more deeply clefted (Fig. 5). In both sexes the tenth sternum disappears and a pair of paraprocts appears instead (Fig. 5, PRP). The cerci attain the normal number of segments, i.e. 15.

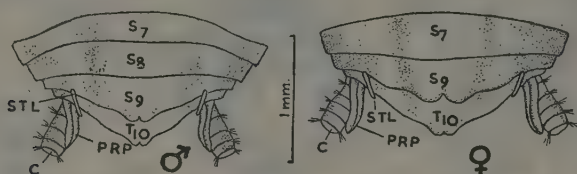


Fig. 5 : Ventral view of terminalia of fourth instar, male and female (PRP, paraproct; other lettering as in Fig. 3).

After another period of about twenty one days, a new moult takes place leading to the fifth instar. In this instar (Fig. 2), the proportional length of the head decreases to one fifth of that of the body (length of the head not exceeding 1.4 mm. and that of the body reaching about 7 mm.). The wing pads have increased a little in size. In the male nine abdominal sterna are distinct, while in the female only seven, the eighth and ninth being completely hidden (Fig. 6). In the latter case the seventh sternum undergoes a considerable change and a notched fold extends from its posterior end. According to

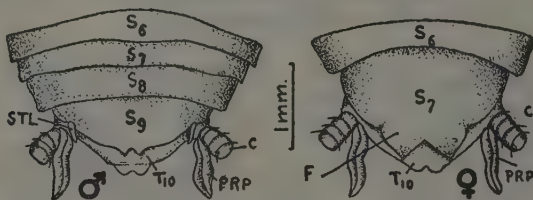


Fig. 6 : Ventral view of terminalia of fifth instar, male and female (F, future subgenital plate; S6, sixth sternum; other lettering as in Fig. 3).

Q a d r i (1940), this fold is intersegmental and represents the future subgenital plate. The fifth instar lasts for about eighteen days, after which another moult takes place leading to the following or sixth instar.

In the sixth instar (Fig. 2) the body is about 8.5 mm. long and the head 1.6 mm. The antennae remain unchanged in the female and undergo a

characteristic change in the male. In the latter case the postpedical is subdivided into a basal cylindrical segment densely covered with setae and one or two distal annular segments similar to the successive brachymeres. The wing pads grow larger and the veins begin to appear. In the female the seventh sternum becomes enlarged forming the future hypogynum (Fig. 7, S7) which conceals the subgenital plate. In the male the ninth sternum becomes also enlarged, giving rise to the future hypandrium (Fig. 7, S9). This instar lasts for about eighteen days after which a new moult takes place leading either to the fully formed male or the last nymphal instar of the female.

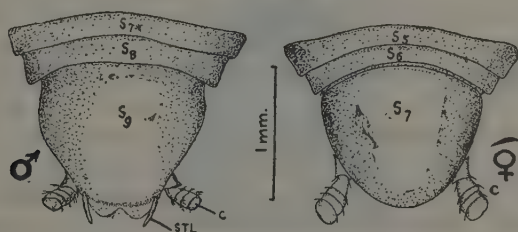


Fig. 7 : Ventral view of terminalia of sixth instar, male and female (S5, fifth sternum; other lettering as in Figs. 3 and 6).

In the last or seventh nymphal instar the body of the female is about 1cm. long. The proportional length of the head decreases to about one sixth of that of the body (its longitudinal axis not exceeding 1.7 mm). The wing pads are prominent and nearly cover the second abdominal tergum. The seventh instar lasts for about twelve days after which the last moult takes place leading to the fully formed female.

4. Moulting

The nymphal development begins by the embryonic moult and is accomplished by a number of nymphal moults.

In the embryonic moult the hatching young gets rid of its enveloping sheath or pellicle. This process begins by the appearance of a narrow slit above the prothorax, through which the head and thorax protrude. The young then struggles to free its antennae and legs. By further squirming movements the torn pellicle is pushed backwards and the abdomen is finally free. Ten minutes may be sufficient for all the young to moult. Immediately after moulting the abdomen is somewhat inflated, but as the young remains motionless for a minute or two, it becomes flat. The young then moves about searching for food and, if not present, the torn pellicle may be eaten up.

The nymphal moult or ecdysis is nearly similar to the embryonic moult, but it takes more time. When this process is about to take place the nymph remains quiet and secluded for two or three days. Then the skin splits along the mid-dorsal line of the prothorax. Through the resulting crack (Fig. 8, D.CR), the prothorax appears first and is followed by the head, and then the

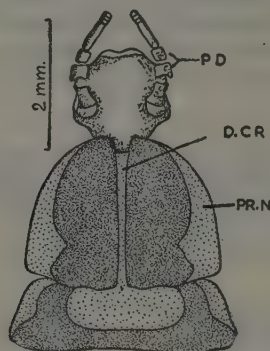


Fig. 8 : Exuvium of last instar, dorsal view (D.CR, dorsal pronotal crack; PD, cracked pedicel; PR.N, pronotum).

same steps of the embryonic moult take place. The whole process may take from 10 to 15 minutes to get rid of the cast skin. The latter may remain attached, however, for one or two hours to the posterior extremity of the body as the nymph moves about. Examination of the exuvium shows that the skin of the antennae is also cracked across the dorsal side of the pedicel (Fig. 8, PD).

Immediately after moulting the body of the nymph is almost milky white except for the eyes and the mandibles. The gut is visible through the transparent body wall. Change in colour is gradual and the normal reddish brown colour is attained within three hours after the embryonic moult and five hours after the nymphal moult. The legs and antennae, however, may remain pale yellow for about two days.

Under somewhat favourable conditions (30°C. and 65% R.H.), the number of moults is six in the male and seven in the female. The average period between moults is almost equal in both sexes, being about 16.7 days in the male and 16.4 days in the female (Table VI).

When the temperature was increased to 32°C. (humidity kept constant at 65% R.H.) the average period between moults became 19.1 days in the male and remained nearly unchanged in the female. About 17% of the males and 14% of the females showed an additional moult, the total number of moults thus being seven in the males and eight in the females. When the

temperature was lowered to 25°C., a considerable prolongation in the period between moults was observed ; the average being 31.2 days in the male and 28.6 in the female (Table VI). The percentage of individuals showing an extra moult increased also to 24 among the males and 17 among the females (Table VI).

Humidity seems also to affect the number of moults as well as the period between moults. Table VII shows the percentage of individuals undergoing an extra moult and the average period between moults at different humidities.

From the above results it is obvious that at 30°C. and 65% to 70% R.H. the period between moults is shortest and nearly equal in both sexes, and no individuals undergo extra moults. It is also clear that at lower temperatures and humidities a marked prolongation in the period between moults takes place in both sexes, and the males showed more tendency to an extra moult than the females.

Starvation also results in an increase in the number of moults. Nymphs fed every other day showed the normal number of moults. Nymphs fed twice a week exhibited an extra moult among 24% of the individuals, and two extra moults among 9.3%. The latter percentage increased to 26% among the nymphs fed once a week.

5. The sex-ratio

To study the sex-ratio a number of the sixth instar-nymphs was collected and reared at a constant temperature and relative humidity of 32°C. and 70% R.H., respectively. The newly formed adults were isolated in pairs (one male and one female each) and reared under the same conditions. The egg-capsules obtained were allowed to incubate under more or less favourable conditions (60% R.H. and 32°C.), so that hatching takes place in the shortest time and the maximum number of nymphs is obtained.

The offspring of each female was isolated in a separate jar. The young of four females were reared under room conditions during the warm season, from April to August (26-36°C. and 50-75% R.H.). The young of four other females were reared under controlled conditions (30°C. and 65% R.H.). The rest of the young were allowed to complete their development and gave a second generation of cockroaches with which another series of room experiments is to be conducted during the cold season from September to April (15-25°C. and 45-65% R.H.).

Under room conditions more females were obtained than males. From the 590 nymphs reaching maturity during summer 268 only were males, the percentage of males thus being about 45.4%.

Under controlled conditions (30°C. and 65% R.H.) the proportions of

both sexes were practically equal. From the 570 nymphs that reached maturity 297 males and 273 females were obtained.

When compared with other cockroaches, it was found that *Supella* and *Blattella* exhibit practically the same sex ratio under controlled conditions. Under room conditions, however, there is always a marked preponderance of females. Results of room experiments conducted by Gould and Deay (1940) at an average temperature of 76°F. (about 24.5°C.) have shown that from 89 nymphs of *Blattella* 39 were males and the rest were females (percentage of males thus being about 43.8), whereas at a constant temperature of 84°F. (about 29°C.) the percentage of males was about 51.8. In *Periplaneta*, on the other hand, the reverse took place and the males became more than the females (61.9%) under room conditions and less (41.5%) under controlled conditions. In *Blatta*, on the other hand, the same authors observed that the proportions of both sexes were almost equal under room and controlled conditions.

IX. THE TOTAL DURATION OF THE LIFE-CYCLE

Under room conditions the total duration of the life-cycle varies according to seasons. Egg-capsules deposited during the warm season (July and August) required an average incubation period of about 38 days. The young hatched in August and September, passed their nymphal stage (about 220 days) during autumn and winter and reached the adult stage in March and April. The adult became sexually mature after about 16 days and the first egg-capsule was deposited. Thus, the total duration of the life-cycle (egg, nymph, and sexually mature adult) was about 274 days. It is also clear that the adult life (about 110 days) is passed during the warm season (May-August).

In the cold season (December and January) the incubation period was much longer, reaching about 90 days. The hatched young passed the nymphal stage during the spring and early summer and reached the adult stage in about 120 days. After about 24 days, the first egg-capsule was deposited and thus the total duration of the life-cycle (from egg to egg) was about 234 days. It is noticed that the adult life (about 130 days) ends in the late summer and autumn.

Under controlled conditions (30-32°C. and 60-70% R.H.) the duration of the life-cycle from egg to egg was about 163 days. About 40 days of this period were passed in the egg-stage, 110 in the nymphal stage, and 13 days before oviposition. The adult life continued for another period of about 75 days.

It is noteworthy that *Supella* passes a relatively long period of its life in the egg-stage. The incubation period is about one sixth of the total life dura-

tion under controlled conditions and about one fifth under room conditions.

With regard to the other common species of cockroaches the observations of Gould and Deay (1940) may be taken into consideration. These authors reared the German, American and Oriental cockroaches at a uniform temperature of about 81.5°F. (27.5°C.). The total life duration (from egg till death) was about 260 days in *Blattella*, 640 in *Periplaneta*, and 865 days in *Blatta*, the incubation period being about 20, 40 and 45 days, respectively. The proportional length of the incubation period to the total life duration was therefore about one thirteenth in *Blattella*, one sixteenth in *Periplaneta*, and one eighteenth in *Blatta*.

X. SUMMARY

(1) *Supella supellectilium* Serv. is found all the year round but more abundant during spring and summer. It is frequent in houses particularly in furnitures. Although it is omnivorous yet it is particularly fond of sweet material especially when flavoured. In a damp atmosphere (about 70% R.H.) it can withstand starvation, the male for about 12 days and the females for about 21 days.

(2) In the cold season the longevity of the adult female is about 184 days and that of the adult male about 152 days. In the warm season the longevity is considerably shorter, being about 116 days in the female and about 95 in the male. The longevity of both sexes is considerably influenced by temperature and not so by humidity. It was about 81 days for the male and 104 for the female at 32°C. and 70% R.H.

(3) The pre-oviposition period is about 28 days in the cold season and 16 days in the warm season. It is more pronouncedly influenced by temperature than by humidity. Under controlled conditions (32°C. and 70% R.H.) it is about 13.2 days

(4) In the cold season the average number of egg-capsules per female is about 6, deposited at average intervals of about 15.5 days. In the warm season the average number of capsules per female is about 13, deposited at average intervals of about 7 days. The rate of oviposition is markedly influenced by temperature and humidity, and the average number of capsules reaches the maximum (about 14.5 per female) at 32°C. and 70% R.H.

(5) After depositing the last egg-capsule the female lives for about 24 days in the cold season and 5 days in the warm season. It was about 4.5 days at 32°C. and 70% R.H.

(6) The two sexes remain in copulation for about 80 minutes and a single mating is sufficient to produce the usual number of fertile capsules. Parthenogenetic reproduction was not observed.

(7) The egg-capsule of *Supella* is small, reddish brown and purse-shaped.

It usually contains 18 eggs, but the maximum number of hatching nymphs is 16. It is carried by the female for about one or two days with its seam upwards and is left uncovered after deposition. The date of hatching is indicated by the appearance of a greenish band near the lower margin.

(8) The incubation period is relatively long and may reach 90 days in the cold season. In the warm season it is shortened to about 38 days. It is considerably influenced by temperature and less influenced by humidity, and is about 34 days at 32°C. and 60% R.H.

(9) The average number of hatching nymphs per egg-capsule is about 12 in the cold season and 15 in the warm season. In the former case none of the egg-capsules give the maximum number of nymphs (16), while in the latter case or under controlled conditions at 32°C. and 60% R.H., about 24% of the egg-capsules yield 16 nymphs each. The nymphs hatch nearly at the same time and those situated at the corners of the egg-capsule are the last to hatch. The hatching is followed immediately by the embryonic moult.

(10) Six nymphal instars are found in the male and seven in the female. The first instar lasts for about 8 days, the second for about 16 days, the third and fourth for about 21 days each, and the fifth and sixth for about 18 days each. The female seventh instar lasts for about 12 days only. The total nymphal duration of the female is about 231 days in the cold season and 119 days in the warm season. That of the male is slightly shorter and the difference ranges between 10 days in the warm season and 19 in the cold season.

The nymphal duration is considerably influenced by temperature and less markedly influenced by humidity, and the shortest durations (about 100 days in the male and 111 in the female) are reached at 30°C. and 65-70% R.H. Under these conditions the number of moults (other than the embryonic moult) is equal to the number of the nymphal instars. At a lower or higher temperature and humidity an additional moult takes place in both sexes; the percentage of extra moults being always higher among the males.

(11) Under room conditions, more females are obtained than males, while under controlled conditions (30°C. and 65% R.H.) the proportion of both sexes is practically equal.

(12) The total duration of the life-cycle (from egg to egg) under room conditions ranges between 7 and 9 months.

XI. ACKNOWLEDGMENTS

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XI. REFERENCES

- Back, E. A. (1937) : The increasing importance of the cockroach, *Supella supellectilium* Serv., as a pest in the United States (*Proc. ent. Soc. Washington*, XXXIX, pp. 205-213, figs. 1 and 2).
- Berland, L. (1929) : Remarques sur le soin que certaines Blattes (Orth.) prennent de leur oothèques (*Bull. Soc. ent. France*, pp. 172-174).
- Bolivar y Peltain, C. (1925) : Sur quelques *Eupelmidae* de l'Egypte [Hymenoptères-Chalcidiens] (*Bull. Soc. Roy. Ent. Egypte*, IX, pp. 139-45 [43-45], 1 fig.).
- Buxton, P.A., and Mellanby, K. (1934) : The measurement and control of humidity (*Bull. ent. Res.*, XXV, pp. 171-175).
- Chopard, L. (1935) : Die Mobelschabe, *Supella supellectilium* Serv., ein neuerdings nach Europa eingeschlepptes Insekt (*Mitt. Ges. Vorratschutz*, XI, No. 4, pp. 51-54, Berlin).
- Cottam, R. (1922) : Observations on the Phyllodromine cockroach, *Blatella supellectilium* Serv., in Khartoum (*Entom. monthly Mag.*, LVIII, pp. 151-158).
- Ebner, R. (1925) : Quelques notes au sujet de *Supella supellectilium* Serv. (*Bull. Soc. R. ent. Egypte*, IX, pp. 198-204, 1 fig.).
- Fischer, O. Von (1927) : Die Entwicklung von *Periplaneta americana* (*Mitt. naturf. Ges. Berlin*, XXVIII, pp. 5-7).
- Flock, R.A. (1941) : The biological control of the brown-banded cockroach (*Bull. Brooklyn ent. Soc.*, XXXVI, pp. 177-181).
- Gomes, J. G. (1942) : Contribution to the classification of Brazilian Chalcididae (*Bol. Esc. nac. Agrom.*, No. 2, pp. 9-45).
- Gould, G. E. (1941) : The effect of temperature on the development of cockroaches (*Proc. Ind. Acad. Sci. (Indiana)*, L, pp. 242-248).
- Gould, G.E., and Deay, H. O. (1938) : Notes on the bionomics of roaches inhabiting houses (*Proc. Ind. Acad. Sci. (Indiana)*, XLVII, pp. 281-284).
- Gould, G. E., and Deay, H.O. (1938) : The biology of the American cockroach (*Ann. ent. Soc. Amer. (Columbus)*, XXXI, pp. 289-498, 1 fig.).
- Gould, G. E., and Deay, H. O. (1940) : The biology of six species of cockroaches which inhabit buildings (*Bull. Purdue Univ. Agric. Exp. Sta. (Lafayette)*, No. 451, 31 pp., 13 figs., 12 tables).
- Griffiths Jr., J.T., and Tauber, O.E. (1942) : Fecundity, longevity and parthenogenesis of the American roach, *Periplaneta americana* L. (*Physiol. Zool. (Chicago)*, XV, pp. 196-209).
- Griffiths Jr., J.T., and Tauber, O.E. (1942) : The nymphal development for the roach *Periplaneta americana* L. (*Journal New-York ent. Soc.*, L, pp. 263-272, 1 fig., 2 tables).

- G u p t a , P. D. (1947) : On copulation and insemination in the cockroach, *Periplaneta americana* Linn. (*Proc. nat. Inst. Sci. India*, XIII, pp. 65-71, 2 figs.).
- H e b a r d , M. (1917) : The Blattidae of North America north of the Mexican boundary (*Mem. Amer. ent. Soc.* (Philadelphia), No. 2, pp. 1-284).
- K h a l i f a , A. (1950) : Spermatophore formation in *Blattella germanica* L. (*Proc. R. ent. Soc. London* (A), XXV, pp. 53-61, 6 figs.).
- K n o w l t o n , G. F. (1942) : Three new pests which invade Utah (*J. econ. Ent.* (Menasha), XXXVI, No. 2, p. 353).
- L a i n g , F. (1946) : The cockroach : its life-history and how to deal with it (British museum [Nat. Hist.], Econ. Ser. 12, 4th edition, 28 pp., 13 figs.)
- L a m b , C. G. (1922) : The geometry of insect pairing (*Proc. R. Ent. Soc. London* (B), XCIII, pp. 1-11).
- L a w r e n c e , T. C. (1938) : A report on *Supella supellectilium* Serv. (Orth.-Blatt.) (*J. Kansas ent. Soc.*, XI, No. 4, p. 123).
- L e v e r , R. J. A. W. (1943) : Entomological notes (*Agric. J. Fiji* (Suva), XIV, No. 2, pp. 40-44).
- M a c k e r r a s , L. M., and P o p e , P. (1948) : Experimental Salmonella infections in Australian cockroaches (*Aust. J. exp. Biol. med. Sci.*, XXVI, part 6, pp. 465-570, 2 figs.).
- M a r l a t t , C. L. (1917) : Cockroaches (U. S. Dept. Agric., Farmer's Bull., No. 658).
- M i a l l , L. C., and D e n n y , A. (1886) : The structure and life-history of the cockroach, *Blatta orientalis* Linn. (Lovell Reeve and Co., London, 224 pp., 125 figs.).
- N i g a m , L. N. (1933) : The life-history of a common cockroach (*Periplaneta americana* Linn.) (*Ind. J. Agric. Sci.* (Calcutta), III, pp. 530-543).
- O l s o n , T. A., and R u e g e r , M. E. (1950) : Experimental transmission of *Salmonella oranienburg* through cockroaches (Publ. Health Rep. (Washington) LXV, no. 16, pp. 531-540).
- P e t t i t , L. C. (1940) : A roach is born (*New England Naturalist* (Boston), VII, pp. 15-18, 9 figs.).
- P r y o r , M. G. M., R u s s e l , P. B., and T o d d , A. R. (1946) : Protocatechuic acid, the substance responsible for the hardening of the cockroach ootheca (*Biochem. J.*, XL, pp. 627-628).
- Q a d r i , M. A. H. (1938) : The life-history and growth of the cockroach *Blatta orientalis* Linn. (*Bull. ent. Res.*, XXIX, pp. 263-276, 7 figs.).
- R a u , P. (1924) : The biology of the roach *Blatta orientalis* Linn. (*Trans. Acad. Sci. St. Louis*, XXV, pp. 57-79).
- R a u , P. (1940 a) : The life-history of the American cockroach, *Periplaneta americana* Linn. (*Ent. News* (Philadelphia), LI, pp. 121-124, 151-155, 186-189, 223-227, and 273-278).

- R a u, P. (1940 b) : The life-history of the wood roach, *Procoblatta pennsylvanica* De Geer (*Ent. News* (Philadelphia), LI, pp. 4-9, and 33-35).
- R a u, P. (1943) : How the cockroach deposits its egg case: a study in insect behaviour (*Ann. ent. Soc. Amer.*, XXXVI, pp. 221-226).
- R a u, P. (1945) : Notes on the life-history of *Periplaneta fuliginosa* Serv. (*Psyche* (Cambridge, U. S. A.), LII, pp. 107-108).
- R e h n, J. A. G. (1916) : The Stanford Expedition to Brazil, 1911, J. C. Brunner Director (*Trans. Amer. ent. Soc.* (Philadelphia), XLII, pp. 215-308, pls. 14-15).
- R e h n, J. A. G. (1947) : African and Malagasy Blattidae [Orthoptera]. Part IV (*Proc. Acad. Natur. Sci. Philadelphia*, LXXXIII, pp. 59-92).
- R o s s, H. H. (1929) : The life-history of the German cockroach, *Blattella germanica* (*Trans. Illinois Acad. Sci.*, XXI, pp. 84-93).
- R o t h, L. M., and Willis, E. R. (1952) : A study of cockroach behaviour (*Amer. Midland Natur.*, XLVII, pp. 66-129, 4 figs., 8 tables).
- S e a m a n s, L., and W o o d r o f f, L. C. (1939) : Some factors influencing the number of moults of the German cockroach (*J. Kansas ent. Soc.*, XII, pp. 73-76, 1 table).
- S e i n Jr., F. (1923) : Cucaraches (Puerto Rico Insular Expt. Sta., Circ. 64).
- S e v e r i n, H. C. (1939) : The brown-banded cockroach in South Dakota (*J. econ. Ent.* (Menasha Wis.), XXII, no. 4, p. 595).
- S h a w, A. E. (1924) : *Supella supellectilium* Serv., a cockroach not before recorded from Australia (*Queensland Nat.*, IV, no. 6, p. 115).
- S h e l f o r d, R. (1906) : 1. Studies of the Blattidae (*Trans. ent. Soc. London*, pp. 231-280).
- S h e l f o r d, R. (1908) : Orthoptera : family Blattidae, subfamily Phyllodrominae (Genera Insectorum (P. Wytzman), fasc. 73).
- S h e l f o r d, R. (1911) : Preliminary diagnosis of some new genera of Blattidae (*Ent. monthly Mag.*, Ser. 11, XLVII, pp. 154-156).
- S h e l f o r d, R. (1912) : The oothecae of Blattidae (*Entomologist's Record* (London), XXIV, pp. 283-287).
- W e r n e r, F. (1905) : Ergebnisse einer zoologischen Forschungsreise nach Aegypten und dem aegyptischen Sudan: I. Die Orthopterenfauna Aegypten mit besonderer Berücksichtigung der Eremitaphilen (*Sitz.-Ber. Ak. Wien*, CXIV, Abt. 1, pp. 357-436, 1 pl.).
- W h e l a n, D. C. (1929) : *Supella supellectilium* Serv. as a household pest in Nebraska (*J. econ. Ent.* (Geneva, N. Y.), XXII, No. 2, p. 421).
- W i l l e, J. (1920) : Biologie und Bekämpfung der deutschen Schabe (*Phyllodromia germanica* L.) (*Monog. Deut. Gesell. angew. Ent.*, No. 5).
- W i l l i a m s, C. B. (1937) : The use of logarithms in the interpretation of certain entomological problems (*Ann. appl. Biol.*, XXIV, pp. 404-414).

- Woodruff, L. C. (1938) : Observations on roach reproduction (*J. Kansas ent. Soc.* (McPherson 2), no. 3, pp. 94-96, 1 fig.).
- Zabinski, J. (1929) : The growth of black beetles and of cockroaches on artificial and incomplete diets: Part 1 (*J. exp. Biol.* (Cambridge), VI, pp. 360-386).
- Zabinski, J. (1933) : Copulation extérieure chez les Blattes (*C.-R. Soc. Biol.* (Paris), CXII, pp. 596-598, 2 figs).
- Zabinski, J. (1936) : Inconstancy of the number of moults during the post-embryonic development of certain Blattidae (*Ann. Mus. Zool. Warsaw*, XI, pp. 237-240, 3 tables).
- Zimmerman[¶], E. C. (1943) : New cockroach parasite from Honolulu (*Proc. Hawaiian ent. Soc.* (Honolulu), XII, p. 20).
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Histology of the digestive tract of the furniture cockroach *Supella supellectilium* Serv.

[Orthoptera: Blattidae]

(with 17 Text-Figures)

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CONTENTS

Introduction — I. Histology of the alimentary canal — II. Histology of the salivary glands. — III. Histology of the Malpighian tubes. — IV. Summary. — V. References.

INTRODUCTION

The histology of the digestive tract of the common species of cockroaches (e.g. *Periplaneta americana*, *Blatta orientalis* and *Blattella germanica*) has been previously studied by a number of workers, notably Petrunkevitch (1899), Ramme (1913), Eidmann (1924), de Toledo Piza (1928), Ross (1930) and Shay (1946).

The review of the literature reveals that no histological studies seem to have been made by previous workers on *Supella supellectilium*. The present work deals with the histology of the alimentary canal, salivary glands and Malpighian tubes of this species. The different structures are, as far as possible, compared with those of other common species.

For making the histological preparations of the digestive tract, hot Bouin solution was used as a fixative and proved suitable. The fixed material was then soaked in cedar wood oil to prevent brittleness. Simple and double embedding methods were used and then 6 micron thick serial sections were

cut. Haematoxylin was used as a nuclear stain, while cosin was found to be a satisfactory cytoplasmic stain.

Illustrations were made with the aid of the camera lucida.

I. HISTOLOGY OF THE ALIMENTARY CANAL

The enteric epithelium lining the alimentary canal rests on a thin basement membrane. The epithelial cells are generally cubical in the stomodaeum, columnar in the mesenteron and cylindrical in the proctodaeum. In the stomodaeum and proctodaeum the epithelial lining is usually thrown into folds and lined internally by a layer or two of cuticular intima of a variable thickness. The latter may be smooth, pitted, ciliated or covered with setae. In the mesenteron, however, the epithelial lining is unfolded and possesses a fairly broad striated inner border.

The muscularis investing walls of the alimentary canal consist of one or more layers of circular and longitudinal muscles. The circular muscles may be interrupted or may form a complete ring around the wall of the alimentary canal. The longitudinal muscles are usually aggregated in bundles and may be branched inside the epithelial folds.

The peritoneal membrane ensheathing the alimentary canal is lost in most parts.

The stomodaeum

The epithelial cells have translucent cytoplasm and usually rounded nuclei. The cell boundaries are indistinct and a syncytium-like structure is thus formed.

The intima is relatively thick and may be smooth, pitted or covered with setae, or may be protruded into ridges or processes.

The muscularis is well developed and is usually separated from the stomodaeal wall by a space filled with connective tissue. The circular muscles are external in position to the longitudinal muscles.

1. The hypopharynx

The wall of the hypopharynx consists mainly of one layer of hypodermis resting on a thin basement membrane and covered with cuticle. The inner lining of the hypopharyngeal wall is composed of relatively large epithelial cells similar in nature to those lining the fore-gut. The space between the hypodermis and the epithelial lining is filled with connective tissue.

The hypopharynx possesses a relatively wide lumen continued with that of the pharynx.

The hypodermis (Fig. 1, HPD) consists of small cubical cells separated

from each other by distinct boundaries. The hypodermal cells are clear in the distal part of the hypopharynx or distilingua (DL), whereas in the basal part or basilingua (BL) they are extinct. The cuticle covering the hypodermis is greatly thickened and hardened in the middle and posterior regions of the hypopharynx, forming the distilingual and basilingual sclerites (DL.S and BL.S). In the apical region of the distilingua, the cuticle is clothed with fine setae.

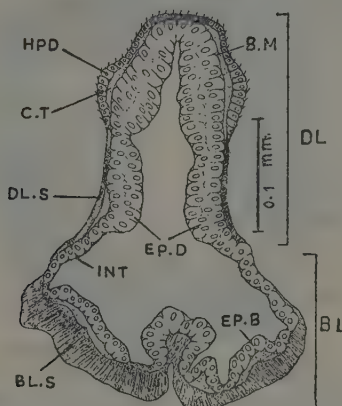


Fig. 1. : Lateral section through the hypopharynx (BL, basilingua; BL. S, basilingual sclerite; B.M, basement membrane; C.T, connective tissue; DL, distilingua; DL.S, distilingual sclerite; EP.B, epithelial lining of the basilingua; EP.D, epithelial lining of the distilingua; HPD, hypodermis; INT, intima).

The epithelium is lined internally with a thin smooth layer of cuticular intima (INT). The cell boundaries are not distinct, which is the case in the epithelial lining of the stomodaeum. In the basal region of the hypopharynx, the epithelial cells (EP.B) are arranged in one row and are cubical with rounded nuclei. In the distal region, however, the epithelial cells (EP.D) are arranged in two rows and are considerably larger with oval nuclei. The epithelium of the hypopharynx rests on a very thin basement membrane (B.M) and is separated from the hypodermis by connective tissue (C.T).

2. The pharynx

The pharynx is a relatively wide short tube differentiated into an anterior larger pharynx anterior, and a posterior smaller pharynx posterior.

The pharynx anterior (Fig. 2), is a muscular wide thick-walled tube to which the dilator muscles are attached. The epithelial cells are relatively large and lined with a thin smooth intima (INT). The epithelial lining of the lateral pharyngeal walls (EP.L) consists of one row of cells with rounded

nuclei situated near the basement membrane. On the other hand, the epithelial lining of the roof and floor (EP.R and EP.F) consists of two rows of large cells with oval central nuclei. In the corners of the pharyngeal wall the epithelium is thrown into few small folds. The basement membrane (B.M) is very thin.

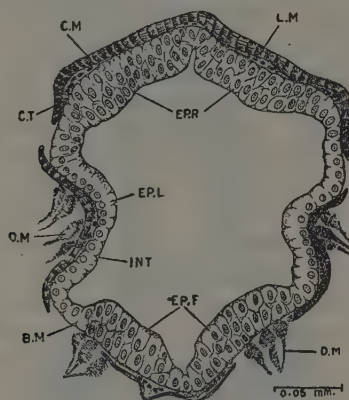


Fig. 2 : Transversal section through the pharynx anterior (B.M, basement membrane; C.M, circular muscles; C.T, connective tissue; D.M, dilator muscles; EP.F, epithelial lining of the floor of the pharynx; EP.L, epithelial lining of the roof of the pharynx; INT, intima; L.M, longitudinal muscles).

The longitudinal muscles (L.M) are very thin and weakly developed. They are scattered in small groups among a narrow space filled with connective tissue (C.T). The circular muscles (C.M) are considerably thick and well developed. They are formed of long striated fibres external in position to the longitudinal fibres. The dilator muscles (D.M) are thick and oblique in position. They are mainly aggregated in the ventral and lateral corners of the pharyngeal walls.

The pharynx posterior is a narrow short tube indicated externally by a constriction between the pharynx and the oesophagus. Its epithelium is folded and consists of one row of small cells with rounded nuclei. The longitudinal muscles are aggregated within the epithelial folds, and the circular muscles are weakly developed.

3. The oesophagus

This is a relatively narrow tube as compared with the pharynx anterior. The intima (Fig. 3, INT) is considerably thick and protruded into numerous blunt cuticular processes (C.PR). In *Blatta orientalis* and *Blattella germanica*,

the intima of the oesophagus carries long pointed needles (Petrunkewitsch, 1899).

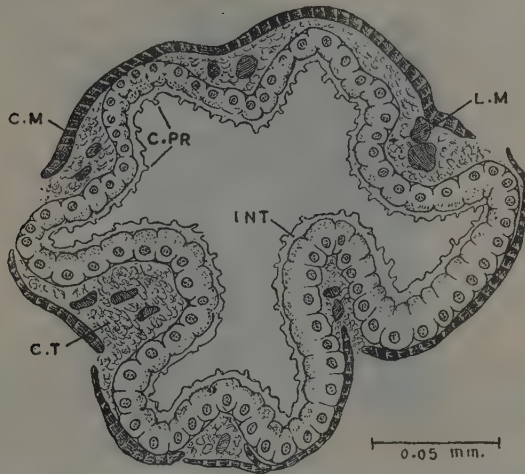


Fig. 3 : Transversal section through the oesophagus (C.PR, cuticular processes; other lettering as in Fig. 3).

The longitudinal muscles (L.M) are thick and arranged in bundles deeply inserted into the folds of the epithelium. The circular muscles (C.M) are slender and separated from the longitudinal muscles by connective tissue (C.T).

The oesophagus widens gradually near its posterior end where the epithelial layer exhibits more folds and furrows.

4. The crop

The crop is a capacious pyriform sac capable of great extension. Its wall consists mainly of the same elements forming that of the oesophagus.

The epithelial cells (Fig. 4, EP) are similar in shape to those of the oesophagus, but the cuticular intima (INT) lining them is much thinner and finely pitted. According to Petrunkewitsch (1899), the porose nature of the intima may increase its permeability, while Snodgrass (1935) believes that the intima of the crop is an actual barrier reducing absorption to a minimum.

The circular muscles (C.M) are slender and disposed at right angles to the longitudinal muscles (L.M), giving the wall of the crop a reticulate appearance. The muscularis is penetrated by fine tracheal endings (T).

The crop narrows abruptly at its posterior end with a marked reduction in the number of the epithelial folds.

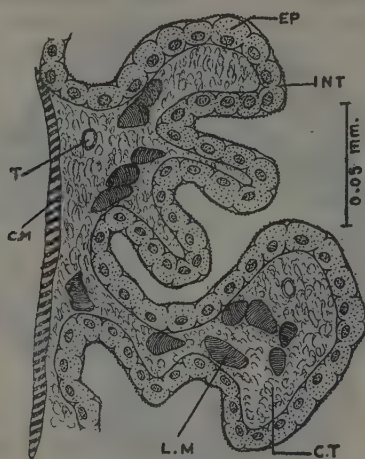


Fig. 4 : Portion of transversal section through the crop (INT, pitted intima; T, tracheal tube; other lettering as in Fig. 2).

5. The proventriculus

As in other cockroaches, the proventriculus possesses highly developed intima and muscularis which are especially adapted for grinding and crushing solid food material.

The proventriculus is divisible into a wider proventriculus anterior and a narrower proventriculus posterior.

In the proventriculus anterior the intima, epithelium and basement membrane are thrown into six major folds enclosing between them several minor ones. The major folds form the well known dental chain characteristic of cockroaches. The minor folds form a series of ridges running longitudinally in between the adjacent teeth.

Two sets of grinding teeth are present, each consisting of three. The teeth vary in shape and size in the various species and in the different individuals of one and the same species. Generally speaking, however, the teeth of one set are triangular in shape, with pointed beak-like apices, whilst those of the corresponding set have flat surfaces resembling those of the molar teeth.

The intima is well differentiated into two distinct layers. The outer layer (Fig. 5, O.C) lying close to the epithelium, is uniform in thickness and dark in colour. The inner layer (I.C) is paler in colour, thicker and harder than the outer layer. It is not uniform in thickness, being considerably

thickened in the distal regions of the grinding teeth. No setae or spicules are present on the cuticular lining of the dental chain, probably due to the wearing out of the teeth (Eidmann, 1924).

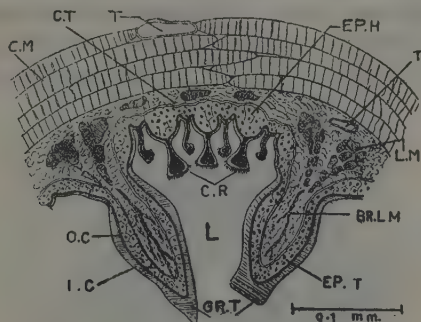


Fig. 5 : Portion of transversal section through the proventriculus anterior (BR.L.M. branches of longitudinal muscles; C.M, circular muscles; C.R, cuticular ridges; C.T, connective tissue; EP.H, heaps of epithelial cells; EP.T, epithelial lining of the grinding teeth; GR.T, grinding teeth; I.C, inner layer of cuticle; L, lumen of proventriculus; L.M, longitudinal muscles; O.C, outer layer of cuticle; T, tracheal tube).

The epithelial lining of the grinding teeth (Fig. 5, EP.T) is continuous with the proventricular epithelium. At the base of each tooth and towards its apex the epithelial layer becomes duplicated but the cell boundaries remain indistinct.

Seven cuticular folds are present between any two adjacent teeth; three of which are larger and more prominent. The folds are filled with heaps of small epithelial cells (EP.H), with indistinct boundaries. From each fold a cuticular ridge (C.R) covered with setae protrudes inside the lumen of the proventriculus (L.) According to Petrunkevitch (1899) these ridges may act as food brushes. The adjacent cuticular ridges enclose between them deep furrows which allow for the passage of the digestive juice from the mesenteron to the crop (Rame, 1913).

The muscularis is well adapted for the forcible contraction of the proventricular walls. The longitudinal muscles (L.M) are aggregated in thick bundles especially developed in the regions of the grinding teeth. In these regions branches of the longitudinal muscles (BR.L.M) extend inside the teeth. The circular muscles (C.M) are thick and tightly interlocked. They are arranged in four concentric layers completely investing the wall of the proventriculus.

In the proventriculus posterior (Fig. 6), the intima (INT) is composed of one cuticular layer of uniform thickness and the epithelial cells (EP) are arranged in one layer. Both of them are thrown into six cushion-like folds (EP.F) protruding inside the lumen of the proventriculus (L) and covered

with long dense setae, which may act as a sieve (Eidmann, 1924).

The longitudinal muscles (L.M) give fine branches inside the epithelial folds. The circular muscles (C.M) are arranged in three concentric layers and are more slender than those of the proventriculus anterior.

According to Eidmann (1924), the proventriculus anterior is chiefly a grinding apparatus, while the proventriculus posterior serves as a cardiac sphincter.

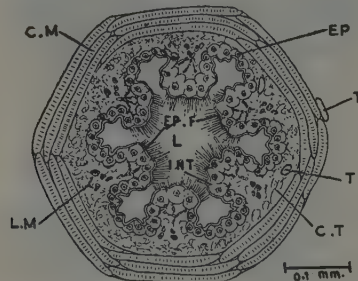


Fig. 6 : Transversal section through the proventriculus posterior (EP, epithelial layer; EP.F, epithelial folds; INT, intima; other lettering as in Fig. 5).

6. The stomodaeal invagination

The epithelial wall of the proventriculus posterior extends inside the lumen of the mesenteron in the form of a funnel-shaped narrow tube. In the anterior part of the mesenteron the epithelial lining of this tube is reflexed; thus being continuous with that of the mesenteric caeca. The structure thus formed is the stomodaeal invagination which corresponds to the oesophageal valve of other insects.

The stomodaeal invagination of *Supella* (Fig. 7, STM.IN) consists of two epithelial lamellae enclosing between them muscular and connective tissues. The inner lamella (I.L) is similar in structure to the enteric wall of the proventriculus posterior. It consists of one layer of cubic epithelial cells lined with a thin intima and thrown into six folds continuous with those of the proventriculus posterior. The outer lamella (O.L) is composed of cylindrical epithelial cells resembling the mesenteric epithelium in shape, but somewhat shorter and lined with a cuticular layer continuous with that of the inner lamella.

The muscular tissue enclosed between the two lamellae (M.S.IN) consists of thin concentric layers of circular muscles to the outside and small bundles of longitudinal muscles to the inside. The latter are grouped in the folds of the inner lamella, but not branching in them.

The stomodaeal invagination does not seem to have the function of a

cardiac sphincter since this function is mainly performed by the proventriculus posterior. It probably serves as an inlet to the mesenteron conducting the food to its lumen.

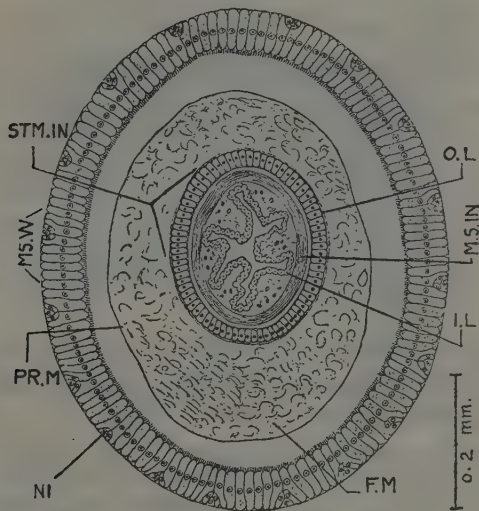


Fig. 7 : Transversal section through the mesenteron in the region of the stomodaeal invagination (F.M, food material; I.L, inner lamella; M.S.IN, muscularis of stomodaeal invagination; M.S.W, mesenteric wall; NI, nidi; O.L, outer lamella; P.R.M, peritrophic membrane).

The mesenteron

The mesenteron, midgut, ventriculus or stomach is a tubular structure limited externally by the mesenteric caeca anteriorly and the bases of the Malpighian tubes posteriorly. Histologically the mesenteron begins at the base of the outer lamella of the stomodaeal invagination.

The wall of the mesenteron (Fig. 7, M.S.W) is unfolded, uniform in thickness and ensheathed by a thin peritoneal membrane (Figs. 8 and 9, P.M), through which fine tracheal branches (T) pass. In *Blatta* and *Blattella*, the inner lining of the mesenteric wall follows a wavy course (Petrunkewitsch, 1899).

The muscularis is weakly developed. It consists of very thin longitudinal muscles (Figs. 8 and 9, L.M) to the outside and slender circular muscles (C.M) to the inside. The longitudinal muscles are mainly aggregated at the bases of the nidi (Figs. 8 and 9, NI).

The mesenteric epithelium is composed of elongated columnar cells with distinct boundaries and oval nuclei. The basement membrane (B.M)

is extremely thin and the cuticular intima is wanting.

Two types of epithelium are present in the mesenteric wall; the digestive and the regenerative epithelium.

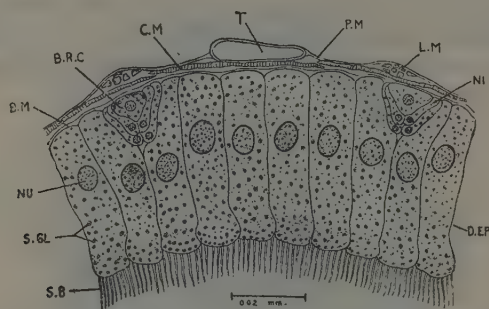


Fig. 8 : Portion of transversal section through the mesenteron (B.M, basement membrane; B.R.C, basal regenerative cell; C.M, circular muscles; D.EP, digestive epithelium; L.M, longitudinal muscles; NI, nidus; NU, nucleus; S.B, striated border; S.GL, secretory globules; P.M, peritoneal membrane; T, tracheal tube).

1. The digestive epithelium

The digestive cells (Figs. 8 and 9, D.EP) lie in a regular row perpendicular to the basement membrane with their boundaries almost parallel to one another. The inner walls exhibit a fairly broad striated border of the honey comb type (S.B.). The cytoplasm is rich in secretory globules (S.GL.). The nuclei (Fig. 8, NU) are not central in position but lie nearer to the basement membrane.

The digestive cells exhibit certain histological variations during the secretory phase, being narrower and more elongated (Fig. 9, D.EP). Their inner walls protrude into translucent spheres (C.SP). The cytoplasm ex-

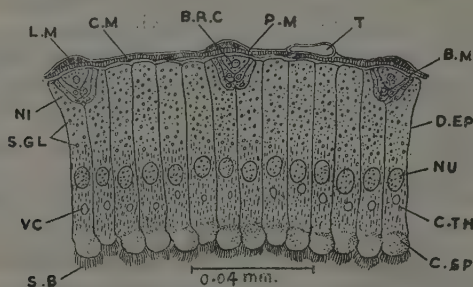


Fig. 9 : Portion of transversal section through the mesenteron in the digestive phase (C.SP, cytoplasmic spheres; C.TH, cytoplasmic threads; CV, vacuoles; other lettering as in Fig. 8),

hibits thread-like structures (C.TH), especially around the nuclei, and small vacuoles (VC) near the peripheral margin. The nuclei (NU) migrate towards the striated border which becomes undulated and irregular.

2. The regenerative epithelium

The regenerative cells are arranged in small pyramid-like heaps or nidi (Figs. 7-9, NI). These are situated between the bases of the digestive cells at intervals of about four or more cells.

Each nidus (Figs. 8-9, NI) consists usually of five small cells with relatively large rounded nuclei. The basal cell of the nidus (B.R.C) is triangular in shape and its nucleus is central in position. It adheres closely to the basement membrane with its broad axis. The rest of the regenerative cells are elongate, super-imposed on one another and have peripheral nuclei.

3. The mesenteric caeca

The walls of the mesenteric caeca consist of the same histological elements forming the ventricular wall. Their lumen, which is continuous with that of the ventriculus, is filled with food materials. The peritrophic membrane (Fig. 7, PR.M) is a distinct tubular structure lying in the lumen of the ventriculus and mesenteric caeca.

The proctodaeum

The walls of the proctodaeum consist of a highly folded layer of cylindrical epithelial cells lined internally with a relatively thin intima.

According to Wigglesworth (1950) the cuticular lining of the proctodaeum is readily permeable to water.

The change in shape and size of the epithelial cells is sudden at the point demarcating the mesenteron from the proctodaeum (Fig. 10, D) where the striated border disappears and the cuticular intima begins.

The muscularis consists of an outer and an inner layer of longitudinal muscles enclosing between them one or two layers of circular muscles. In certain parts of the proctodaeum the inner layer of longitudinal muscles is absent.

1. The pyloric valve

The entrance of the ileum is slightly widened into a sort of a chamber, the pyloric chamber (Fig. 10, PL. CH), in which the Malpighian tubes (M.T) open. At the posterior end of the pyloric chamber the hind-gut epithelium gives a fold projecting into its lumen. This fold is the pyloric valve (PL.V) which is of the proctodaeal type. It is lined internally with the cuticular

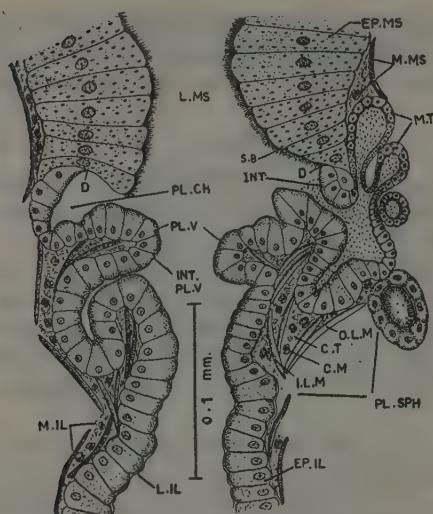


Fig. 10: Lateral section through the pyloric valve (C.M, circular muscles; C.T, connective tissue; D, point of demarcation between mesenteron and proctodaeum; EP. IL, epithelium of ileum; EP.MS, epithelium of mesenteron; I.L.M, longitudinal muscles; INT, intima of ileum; INT. PL. V, intima of pyloric valve; L. IL, lumen of ileum; L.MS, lumen of mesenteron; M.MS, muscularis of mesenteron; M.T, Malpighian tubes; PL.CH, pyloric chamber; PL.SPH, pyloric sphincter; PL.V, pyloric valve; O.L.M, outer longitudinal muscles; S.B, striated border of mesenteron).

intima (INT.PL.V) characteristic of the hind-gut epithelium. The cells forming the pyloric valve are cylindrical in shape and similar in nature to those forming the wall of the ileum.

The muscularis is fairly well developed just below the pyloric valve. It consists of two or three layers of stout longitudinal muscles (O.L.M and I.L.M) enclosing between them doubled circular muscles (C.M). In this region the strengthened wall of the ileum may form a sort of a pyloric sphincter (PL.SPH).

2. The ileum

The epithelial cells lining the wall of the ileum are short and cylindrical with translucent cytoplasm (Fig. 11, EP). The nuclei (NU) are oval and situated nearer to the basement membrane (B.M). The epithelial folds are filled with loose connective tissue (C.T).

The outer longitudinal muscles (O.L.M) are dispersed while the inner ones (I.L.M) are aggregated inside the epithelial folds. There are two layers of circular muscles in close connection with one another (C.M).

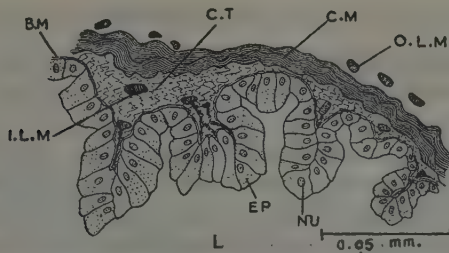


Fig. 11 : Portion of transversal section through ileum (B.M, basement membrane; C.T, connective tissue ; NU, nucleus; other lettering as in Figure 10).

3. The colon

This is well demarcated from the ileum by its wider lumen. The epithelial folds of the colon are larger and fewer in number than those of the ileum. The epithelial cells are larger and more elongated and the cytoplasm is filamentous in appearance (Fig. 12, F.C). The intima (INT) bears long dispersed bristles (C.BR).

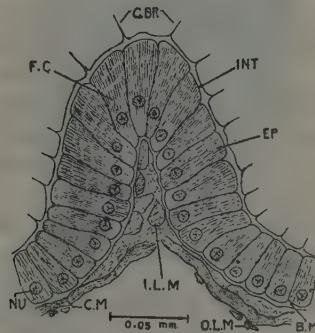


Fig. 12: Portion of transversal section through the anterior region of colon (B.M, base-ment membrane; C.BR, cuticular bristles ; C.M, circular muscles ; EP, epithelium; F.C, filamentous cytoplasm; I.L.M, inner longitudinal muscles ; O.L.M, outer longitudinal muscles; INT, intima ; NU, nucleus).

There is only one layer of fairly thick circular muscles (C.M). The inner longitudinal muscles (I.L.M) are aggregated in the epithelial folds and more bulky than the outer ones (O.L.M). In the posterior narrow region of the colon where it joins the rectum the epithelial cells become smaller and the epithelial folds narrower. The bristles covering the intima and the inner longitudinal muscles are both absent.

4. The rectum

The epithelium of rectum (Fig. 13, EP.R) is continuous with that of the posterior region of the colon (EP.C). It is highly developed in six regions of the rectal wall forming the so called rectal pads (R.P). Each pad consists of two or three rows of columnar epithelial cells. The cells of the basal row (Fig. 14, B.EP.R) are nearly triangular in section while those of the distal row (D.EP.R) are elongate. The latter have striated borders (S.B) resembling those of the mesenteron. They are lined also with a thin layer of smooth intima (INT). The cytoplasm of the rectal epithelium is filamentous in appearance and the nuclei are oval and central in position.

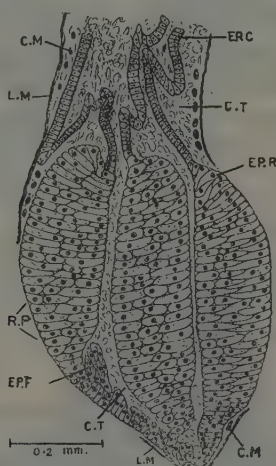


Fig. 13 : Tangential section through the region of junction between colon and rectum (C.M, circular muscles; C.T, connective tissue; EP.C, epithelial lining of colon; EP.F, epithelial fold; EP.R, epithelial lining of rectum; L.M, longitudinal muscles; R.P, rectal pads).

According to Petrunkevitch (1899) the rectal pads of *Blatta* and *Blattella* may secrete a fluid to facilitate the movement of the faeces. Wigglesworth (1950) however, pointed out that the rectal pads have a glandular function only in higher insects, while in cockroaches they probably serve to absorb the excess of water from the contents of the rectum, transforming them into dry faecal pellets.

The space enclosed between any two adjacent pads contains three small epithelial folds (Fig. 14, EP.F), the median of which being the smallest. Each of these folds consists of a single layer of cubic cells lined with a thin intima. Between these folds the intima is thicker and adjacent to the basement membrane (INT-B.M),

The longitudinal muscles (L.M) are arranged in six bands running along special furrows distributed regularly between the rectal pads. Internal to these muscles there is one layer of thin circular muscles (C.M).

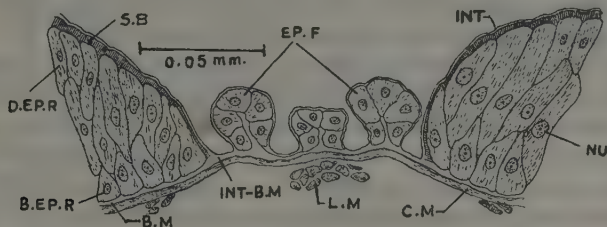


Fig. 14 : Portion of transversal section through rectum (B.E.P.R, basal epithelial row; B.M, basement membrane; C.M, circular muscles ; D.E.P.R, distal epithelial row; E.P.F, epithelial folds; INT, intima; INT-B.M, fused intima and basement membrane ; L.M, longitudinal muscles; NU, nucleus; S.B, striated border).

II. HISTOLOGY OF THE SALIVARY GLANDS

The acini (Fig. 15, AC) consist of numerous relatively large nuclei (NU) irregularly scattered in a non-cellular flocculent cytoplasm.

The efferent salivary ducts (EF.D) have thin walls consisting of flat epithelial cells with indistinct boundaries.

The wall of the glandular salivary duct (L.GL.D) is relatively thick and consists of cubical epithelial cells ensheathed in a thin peritoneal membrane and lined internally with a very thin intima.

The salivary reservoir (Fig. 16) has a relatively thick wall consisting of polygonal epithelial cells (EP) with exceedingly thin walls and central rounded nuclei. It is surrounded by a structureless connective tissue layer of considerable thickness (C.T). This is surrounded by a thin peritoneal membrane (P.M).

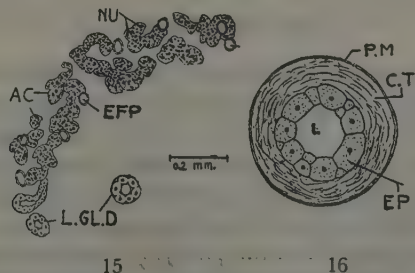


Fig. 15 : Transversal section through the salivary glands (AC, acini; EF.D, efferent duct ; L.GL.D, lateral glandular duct ; NU, nucleus). — Fig. 16 : Transversal section through the salivary reservoir (C.T, connective tissue; EP, epithelial lining; L, lumen; P.M, peritoneal membrane).

III. HISTOLOGY OF THE MALPIGHIAN TUBES

Histologically the Malpighian tube (Fig. 17) is ensheathed in a relatively thick connective tissue layer (C.T) supplied with tracheal endings (T). This is followed by an epithelial layer (EP) resting on a thin basement membrane (B.M) and lined internally by a relatively thick intima (INT).

In the basal part of the Malpighian tube (Fig. 17,A), the epithelial cells are cubical in shape and the intima is richly covered with fine cilia. The lumen is rounded and crowded with granules and crystals of waste material.

In the distal part (Fig. 17, B), however, the Malpighian tube is narrower and slightly flattened. The epithelial cells are larger and flattened, and their inner walls are irregular and protruding into the narrow lumen. The nuclei are larger and the cytoplasm is impregnated with excretory material. The intima is irregular and non-ciliated. The histological study of the Malpighian tubes shows that they belong to the small intestine.

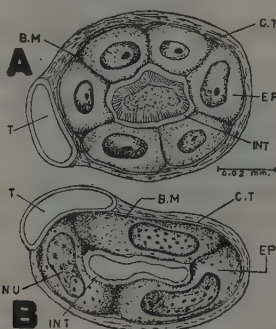


Fig. 17: Transversal section through Malpighian tubes (A, basal part; B, distal part; B.M, basement membrane; C.T, connective tissue; EP, epithelium; INT, intima; NU, nucleus; T, trachea).

IV. SUMMARY

The histological study of the digestive tract of *Supella* reveals that :

(1) The epithelial lining is duplicated in the distillingua, in the roof and floor of the pharynx, at the apices of the proventricular teeth and at the bases of the ridges between them and at the regions of the rectal pads.

(2) The epithelial lining of the mesenteron is unfolded and the striated border lining the digestive cells is of the honey comb type.

(3) The intima is smooth in the pharynx, ileum and rectum; while it is pitted in the crop and produced into blunt prolongations in the oesophagus, and into sharp ridges in the proventriculus anterior, and bears long setae in the proventriculus posterior and the colon,

(4) The epithelial lining of the rectal pads exhibits both the cuticular intima and striated border.

(5) The muscularis is weakly developed in the mesenteron and strongly developed in the proventriculus and near the pyloric valve. The longitudinal muscles are particularly weak in the pharynx and markedly well-developed at the bases of the proventricular teeth and between the epithelial folds of the ileum and colon. The circular muscles are doubled in the ileum and pyloric sphincter, and still more duplicated in the proventriculus.

(6) The peritoneal membrane investing the alimentary canal is lost, except around the mesenteron.

(7) The stomodaeal invagination is weakly developed and seems not to have the function of a specialised cardiac sphincter.

(8) The pyloric valve is of the proctodaeal type.

(9) The acini consist of non-cellular flocculent cytoplasm with scattered nuclei. The salivary reservoir consists of one layer of large polygonal epithelial cells with exceedingly thin walls surrounded by a considerably thick structureless connective tissue.

(10) In the basal part of the Malpighian tube the epithelial cells are cubical with a richly ciliated intima, whereas in the distal part the epithelial cells are larger, fewer in number and flattened with irregular inner walls and non-ciliated intima.

V. REFERENCES

- De Toledo Piza Jr., S. (1928) : Contribuicao para o conhecimento do organizacao dos Blattideos (O tubo digestivo de *Leucophaea surinamensis*) (*Bol. agric. San Paulo*, XXIX, pp. 666-676, 11 figs.).
- Eidmann, H. (1924) : Untersuchungen ueber die Morphologie und Physiologie des Kaumagens von *Periplaneta orientalis* L. (*Zeits. wiss. Zool.*, CXXII, pp. 281-309, 10 figs., Leipzig).
- Konek, S. K. (1924) : Zur Histologie ueber Rukendruse unserer einheimischen Blattiden (*Zeits. wiss. Zool.*, CXXII, pp. 310-322, 13 figs. Leipzig).
- Miall, L.C., and Denny, A. (1886) : The structure and life-history of the cockroach, *Blatta orientalis* Linn. (Lovell Reeve and Co., London, 224 pp., 125 figs.).
- Petrunkewitsch, A. (1899) : Die Verdauungsorgane von *Periplaneta orientalis* und *Blatta germanica*. Histologische und physiologische Studien (*Zool. Jahrb. Anat.*, XIII, pp. 171-190, taf. 11, Jena).
- Ramme, W. (1913) : Die Bedeutung des Proventriculus bei Coleopteren und Orthopteren (*Zool. Jahrb. Anat.*, XXXV, pp. 419-456, 3 Taf., Jena).
- Ross, H. H. (1930) : Notes on the digestive and reproductive systems of the German cockroach (*Trans. Illinios Acad. Sci.*, XXII, pp. 206-216, 15 figs.).

- Shay, D. E. (1946) : Observations on the cellular enclosures of the mid-gut epithelium of *Periplaneta americana* (*Ann. ent. Soc. Amer.*, XXXIX, pp. 165-169, 4 figs., Columbus).
- Snodgrass, R. E. (1935) : Principles of insect morphology (McGraw-Hill Book Co. Inc., New York and London, iv+667 pp., 319 figs.).
- Wigglesworth, V. B. (1950) : The principles of insect physiology (Methuen and Co. Ltd., London, 4th. edition, revised, viii+544 pp., 355 figs.).
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Studies on the "Kew Bug",

Orthezia insignis Browne

[Coccoidea-Ortheziidae]

(with 1 Distribution Map, and 15 Graphs)

by Y. M. EZZAT, B. Sc., M. Sc. (Egypt), Ph. D. (U. S. A.),
Department of Entomology, University of Assiut (Egypt).

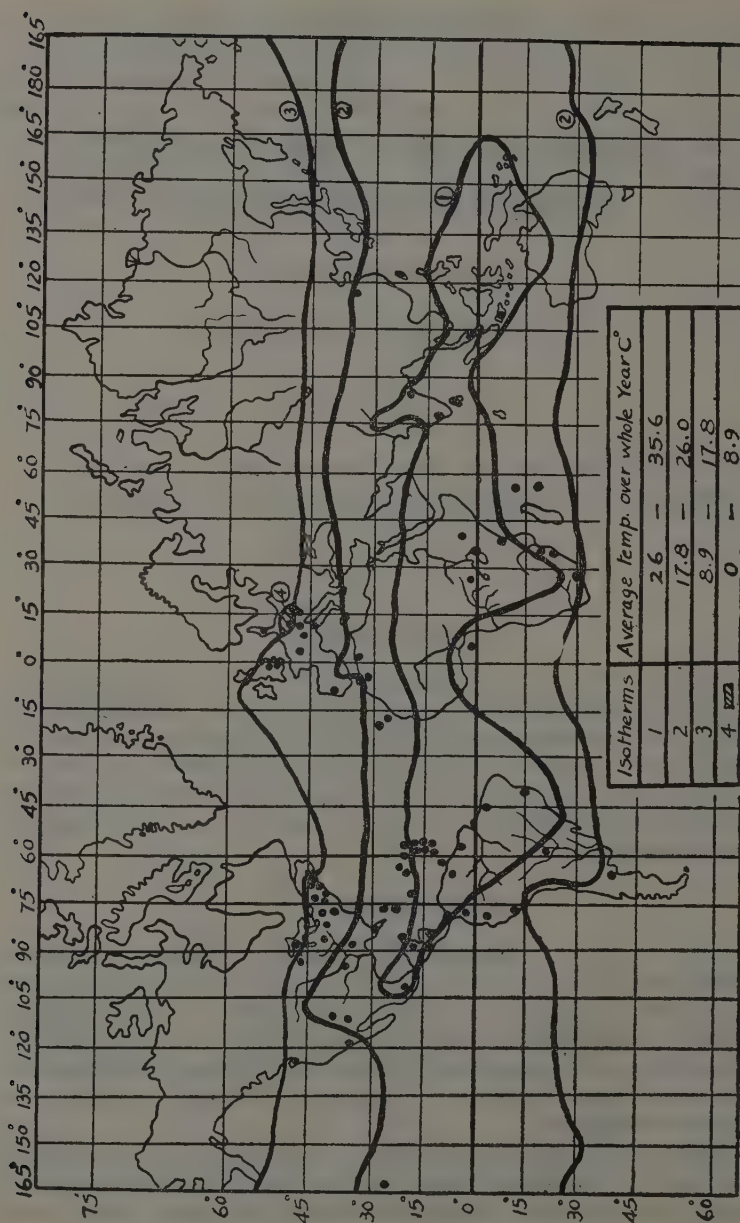
FOREWORD

Considering the economic importance of this pest, the author has undertaken its study in order to prevent its further establishment or spreading. The laboratory work was accomplished in the Department of Entomology of the Ministry of Agriculture, in Cairo, under the direction of Mr. M. Hosny to whom the writer is greatly indebted. Thanks are also due to Prof. Dr. Hamed Seleem Soliman for his kind help and useful suggestions.

INTRODUCTION

Dr. Morrison's discussion (1952) settled the matter of authorship considering that Browne and not Douglas is the real author of *Orthezia insignis*. This species was discovered in Kew Gardens, England, on *Strobilanthus flaccidifolius*, a plant of Chinese origin; hence, arose the viewpoint that China is the native land of this insect. There are views, however, considering the British Guiana to be the place from which this insect was introduced into England.

When first discovered in Kew Gardens, *O. insignis* was given the name of "Kew bug". In Ceylon and India it is known as the "Lantana bug" since it had been introduced there to help in eliminating the lantana weed. In the

Distribution of *Orthozia insignis* Browne

U.S.A., the insect is known as "the white-tail mealybug" or "the green-house *Orthezia*". In Germany, Schumacher found it for the first time inside a greenhouse in Hamburg and gave it the name of "the greenhouse bug". In Natal, it is called "the sugar-iced bug".

Had the damage done by this insect in Egypt been wholly confined to plant fences, it would have been considered of minor economic importance, but the host-plant list of this pest is endless, including many crops of major economic importance in Egypt, such as : farm crops as sugar cane, orchard crops as *Citrus* trees and olives, truck crops as potatoes, vegetables as tomatoes, ornamentals as chrysanthemums, shade trees as *Jacaranda*, and wind screens as *Casuarina*.

It is evident, from the economic literature, that this pest deserves all attention. To assure this statement, the following investigations can be consulted : Bodge (1914), Ramachandra Rao (1920), Subramania (1932), Salmon de los Heros (1933), Ritchi (1935), and Morrison (1925 and 1952). These workers discussed the destructive effect of this pest and its wide host adaptability. Such characters should put *O. insignis* in the black list everywhere it goes.

As to the geographical distribution of *Orthezia insignis*, Dr. Morrison (1952) had to add many localities to his records of 1925, another evidence that this insect continuous to attract attention, and to spread throughout the world. The included distribution map illustrates as accurately as possible the recent situation of this insect. In addition, *O. insignis* was also reported from Australia, Canada, Japan and U.S.S.R., but the exact localities in these areas were not mentioned

MORPHOLOGY

Body of live adult female brownish olive green, oval, about 1.5 mm. long and 1.3 mm. wide; margin with 10 pairs of white waxy processes; dorsum with 12 pairs of waxy processes arranged in 2 median longitudinal rows slightly curving outwards leaving a bare area showing the green colour of the body, posterior pair longest and projecting upwards and a little backwards; venter with white waxy incomplete circles around rostrum and limbs, and a pair of white lamellae projecting backwards from between the posterior legs, venter of young adults with waxy processes projecting from a sclerotized submarginal belt that gives rise in the ovipositing adults to a long white ovisac; the ovisac is constructed of firm but brittle waxy plates, varies from about 1.5 to 3.5 mm. long, nearly parallel-sided, slightly curved upwards posteriorly, with a dorsal opening at the posterior end acting as an outlet for the new hatch, unlike other groups of mealybugs, this insect moves easily carrying its ovisac; antennae 8-jointed, brownish, about 0.9 mm.

long, terminal joint longest; eye bases conical, blackish at apex; rostrum faintly 2-jointed, about 0.2 mm. long; legs with small trochanter closely fused with femur, claw with a minute but distinct denticle on its inner edge, posterior leg longest, about 1.5 mm. long.

First instar larvae generally similar to young adult female but smaller, about 0.3 mm. long; the two median dorsal waxy rows do not separate to leave a bare green area between them; submarginal ventral abdominal waxy processes wanting; antennae 6-jointed. Second instar larvae similar to those of the first instar except in size, but still with 6-jointed antennae. Third instar larvae larger, with submarginal ventral waxy lamellae and 7-jointed antennae.

Adult male has never been recognized in Egypt up till now. Therefore, it may be considered that the reproduction of *O. insignis* in this Country is parthenogenetic. Green (1922) described the male, also giving the differences between certain immature instars of males and females.

While space is not available for more morphological discussion, attention has to be drawn to the keys established by Dr. Morrison in 1928 and in 1952 for specific identification.

BIOLOGY

The following investigators had published their studies and observations about the biology of *O. insignis*: Green (1922), James (1939), Kunhi Kannan (1920), Pinky (1945), Severin (1924), and Weigel (1923). In Egypt, however, the biological studies about this insect has been achieved as discussed in the following paragraphs.

Technique

On examining infested plants at any time of the year, one can always find all the instars of *O. insignis*, from the newly hatched larva to the adult female with its well developed ovisac. Therefore, the insect breeding was started by collecting newly hatched larvae about the beginning of each month and placing them on sprouting potato tubers. The bred insects were registered in cards, each of which carries detailed notes about the life-history of one insect. Out of these cards, tables were arranged to represent the life duration of each stage, taking into account to group the bred insects isothermally, beginning with the highest temperature downwards. To make these tables more comprehensible, graphs were drawn for each stage separately, relating the duration to the temperature. The following discussion will be supported by the Graphs only.

The egg

Incubation period

It is known that the adult female lays its eggs inside the waxy ovisac and if this ovisac is removed, egg laying will be interrupted. This being the case, it has to be assumed that the first egg is laid as soon as the insect produces enough matter of the ovisac adequate for egg laying. It has been found by opening several ovisacs at the beginning of their construction that the part necessary for oviposition, is formed just after the ventral and dorsal surfaces of the sac have joined together constructing a portion about 0.25 mm. long. The date, on which each ovisac of the bred insects reached about that length, is recorded in the insect's card and considered as the date of laying the first egg.

On the other hand, this first egg cannot be kept under observation until natural hatching out of the ovisac. Therefore, the first larva emerging from the ovisac is considered as the larva of the first egg. This is the nearest thing to what actually happens and makes no much difference in the final results, especially when it is considered that there is a comparatively big number of eggs inside the ovisac and that the period between laying the first egg and the emergence of the first larva is rather long.

Graph I represents the incubation period in relation to temperature. The full line curve, joining the encircled points, gives the relation between the average incubation period and the average temperature. Two dotted curves of the same character are drawn to show the maximum and minimum incubation periods at different temperatures. The Graph shows that the average shortest incubation period is about 23.2 days (20.8-26) at 30°C.

It was noticed from the examination of ovisacs, after the death of insects, that the highest number of dead eggs was in ovisacs that passed through an average temperature of 34°C. during the incubation period. This phenomenon suggests that the average curve for this period may be continued till the eggs begin to die at about 34°C.

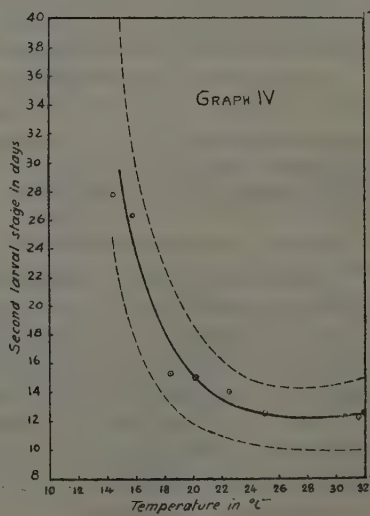
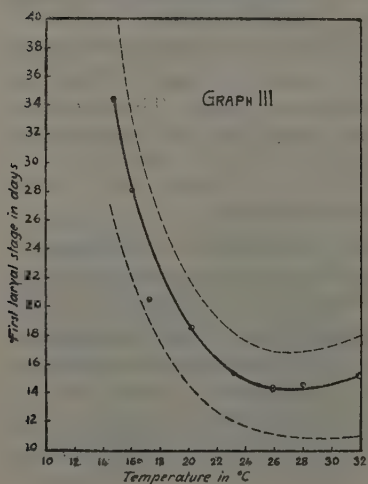
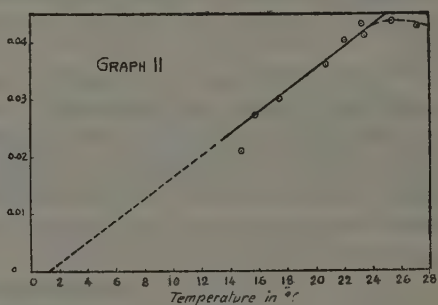
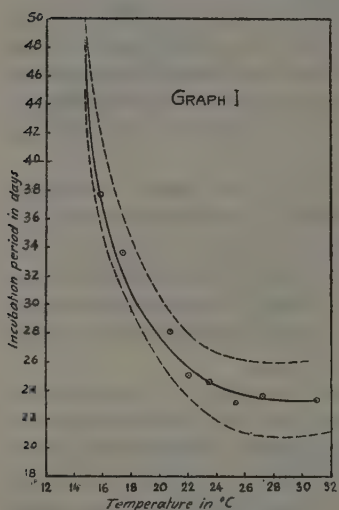
Zero of development

If the theory "Days \times Effective degrees of temperature = Constant" is applied here, it will be seen, as a result of 31 calculations, that the so-called zero of development in the egg is 1.3°C. This becomes fairly clear from Graph II in which the reciprocal of the incubation period, that is the proportional daily amount of development in the egg, is plotted against temperature. The extension of the main line cuts the temperature line at the zero of development (1.3°C). The Graph shows that this theory holds fairly well between about 15 and 25°C., but it does not work above 28°C. though life is possible up to about 34°C.

Percentage of hatching

Out of a total number of 1556 eggs, only 158 failed to hatch. This gives a result of 89.8% hatching or, in other words, 10.2% natural mortality.

GRAPHS I-IV



The larva

Larval stages

This insect moults three times, and the date of moulting can be accurately recorded. Therefore, it is easy to recognize in the metamorphosis of *Orthezia insignis* three larval instars, each with a definite larval stage. Graphs III, IV, and V represent the 1st, 2nd, and 3rd larval stages successively. In each Graph, the full line curve joining the encircled points gives the relation between the average temperature and the average duration, while the two dotted curves are drawn to illustrate the maximum and minimum durations at different temperatures. It is obvious that as the temperature decreases or increases around the average optimum temperature for each stage, the duration increases; but the rate of increase is much greater in the direction of lower temperatures.

Graph VI represents the total larval stage. The full line curve (a), passing by the encircled points, is drawn for the average duration of the whole larval stage; that is the period between hatching and 3rd moult, plotted against the average temperatures. The two dotted curves, of the same nature, represent the maximum and minimum durations at different temperatures. The fourth curve (b), joining the crossed points, is drawn from addition of the average curves appearing in Graphs III, IV, and V. This curve (b) is rather theoretical, as the three larval stages are assumed to occur at the same temperature, while curve (a) is drawn from actual observation. At a high temperature, curve (b) gives a lower value of duration than curve (a), as the three stages are supposed to happen at the same high temperature, while actually the larva may have passed through a lower temperature which may need a longer duration, in any of its three stages, as represented in curve (a). Similarly, at a lower temperature, curve (b) gives a longer duration than curve (a), as the three instars are supposed to occur at the same low temperature, needing more time than if any one of the three stages occurs at a higher temperature, which actually happens as shown by curve (a).

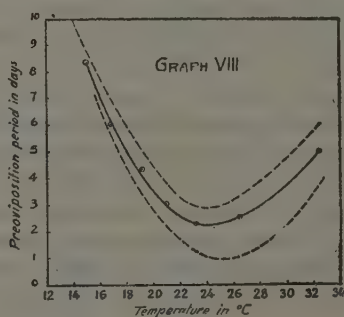
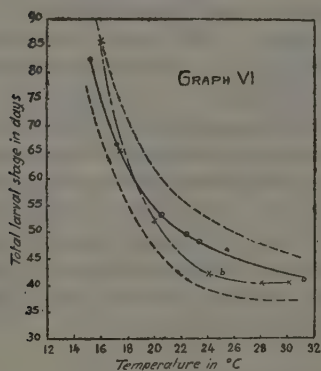
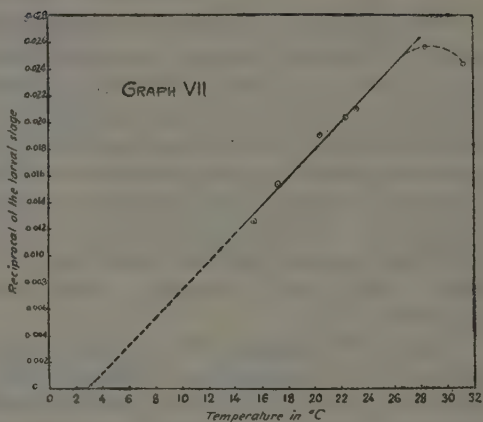
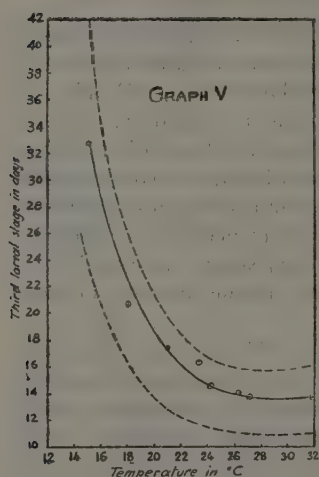
Zero of development

Applying the same rule as in the case of the egg, it appears that the zero of development in the whole larval stages is 2.9°C. This condition is represented in Graph VII.

Natural mortality

The percentage of this mortality is not the same in all the larval stages. It is comparatively high during the 1st stage, about 31.4%, probably because of two reasons : Firstly, when a larva dies at the outlet of the ovisac, other

GRAPHS V-VIII



larvae may be locked in and consequently die. Secondly, the difficulty that the newly hatched larva encounters to settle on the host plant, especially on the hairy potato sprouts used for breeding, makes a comparatively big number of the 1st instar larvae fail to settle, and starve. On the other hand, the natural mortality is only 8.9% during the 2nd larval stage and 7.9% during the 3rd one. Generally calculated, the natural mortality may be considered as about 42.4% for the whole larval stage.

The adult female

Pre-oviposition period

This period is the time elapsing between the date of the third moult and that of laying the first egg. These two dates have been discussed in previous stages. Graph VIII represents the average, minimum, and maximum pre-oviposition periods at different temperatures.

Oviposition period

In addition to the date of laying the first egg, the date of laying the last egg is here required. Since this last egg, as well as any other egg is laid inside the ovisac, it has to be assumed that the last larva emerging from the ovisac is the hatch of the last egg laid. In certain cases, however, there may be inside the ovisac, after the death of the mother insect, few dead larvae or eggs which are more laible to be laid after that egg of the last emerging larva; but the number of these left-overs is too small to affect much the final result. After having known the date of hatching for the last egg and the temperature range preceding this date, the average curve in Graph V can be used through the so-called "trial and error" method to get the incubation period for this egg. By subtracting this period out of the hatching date, the date of laying the last egg is obtained. Now both dates required are known and the oviposition period have been calculated for several cases and represented in Graph IX.

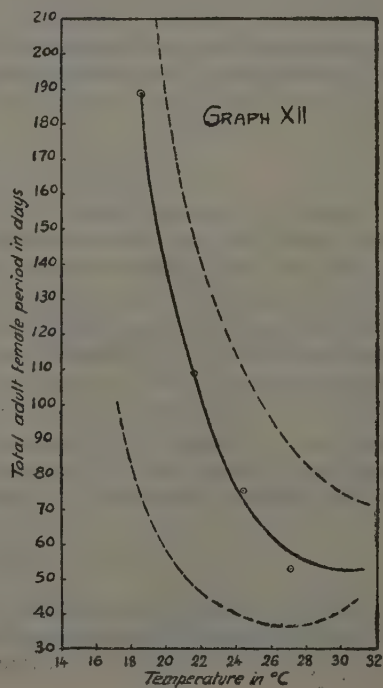
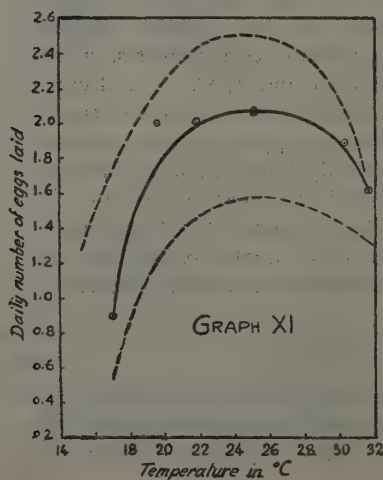
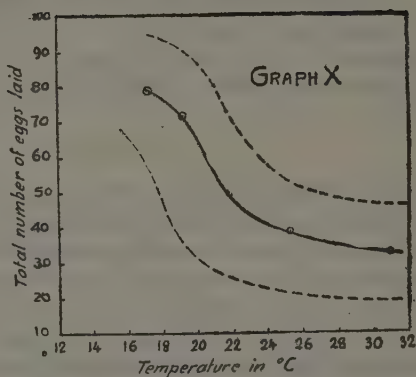
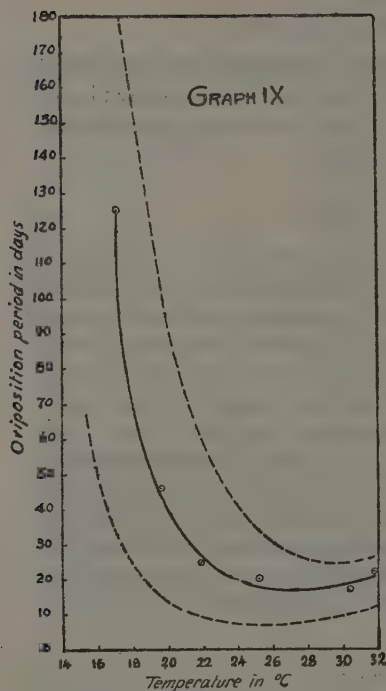
Number of eggs laid

Graph X represents this number at different temperatures. The average curve shows that the largest number of eggs laid is 79 (58-95), occurring at 17°C. As the temperature increases the number of eggs decreases, but the rate of this decrease is much greater between 17 and 22°C. The decrease in the total number of eggs laid at higher temperatures is only due to a shorter oviposition period at such temperatures. This is supported by the fact that the average daily number of eggs laid is usually larger at warm weather. Graph XI illustrates the daily number of eggs laid against temperature. It shows that the average for this number is about 2 eggs at 25°C, and as the temperature varies around this optimum, the daily number of eggs decreases at nearly the same rate, though the right arm of the curve is slightly shorter.

Adult female stage

This stage is represented in Graph XII, in which the full line curve gives the relation between the average temperature and the average duration of the adult stage. It shows that the average optimum duration is about 52.5

GRAPHS IX-XII



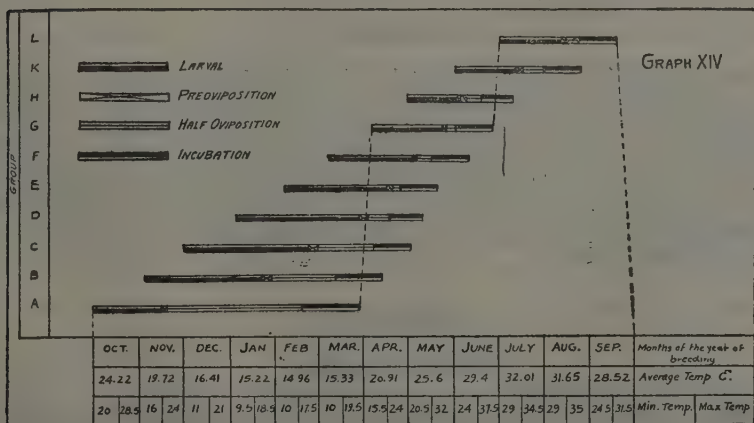
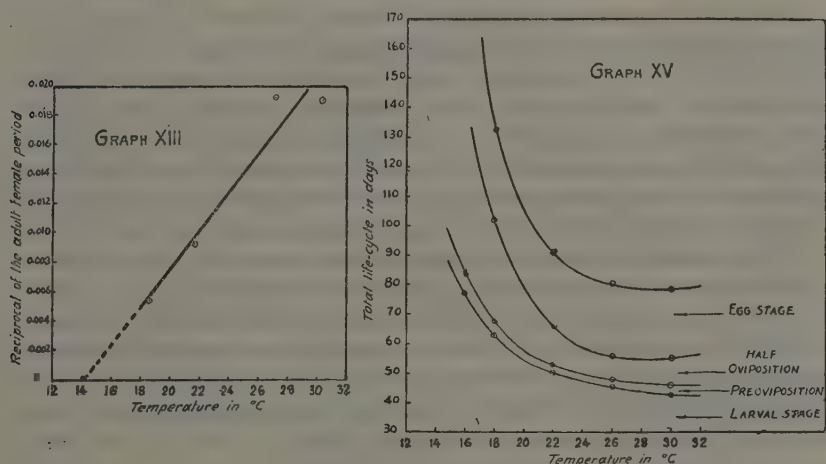
days at about 30°C. Obviously, this is the longest stage of the insect owing to the long oviposition period, specially in cold weather.

Zero of development

Through the same way followed in the previous stages, Graph XIII is obtained to illustrate the zero of development for the adult female stage. It shows that the development of the adult female stops at about 14.3°C.

During the experimental work it was noticed that the insects which passed, while adults, through a temperature lower than 14.3°C, mainly

GRAPHS XIII-XV



between the beginning of January and March, had the longest adult durations (101-220 days). Apparently, these insects had passed in that cold weather through what might be considered as periods of unreal hibernation, during which they stayed motionless on the breeding sprouts. Most of these insects, as recorded in their breeding cards, passed this hibernation during oviposition, and therefore having the longest oviposition periods. During the emergence of larvae out of the ovisacs of these insects, several days passed without any emergence, probably in respect to these days of hibernation during which oviposition had been interrupted.

Number of generations

Graph XIV represents ten groups of insects, indicated by letters A to I, and starting as new hatch about the beginning of each month of the experiments' period. For each group, the Graph illustrates the average of the larval, pre-oviposition, half oviposition, and incubation periods. Only half the oviposition period is recognized here, considering the egg laid at the middle of this period as a representative. The incubation period of this middle egg is calculated, for each group, by the trial and error method through the help of Graph I and the temperature records preceding its hatching date.

It is obvious from Graph XIV that there are about three generations a year on an average. Owing to the fact that there is a long oviposition period and eggs do not hatch about the same time, the life cycle can never be in definite broods, but the different generations must overlap. The longest life cycle is the one started in October and the following cycles becomes gradually shorter (chiefly according to decrease in the oviposition period), until the shortest life cycle is reached in May and June.

Life cycle

The complete life cycle (from hatch to hatch) is illustrated by Graph XV, obtained from the previous average curves for the different stages. Points of this Graph are chosen at temperatures of 16, 18, 22, 26, and 30°C. At these temperatures, the larval, pre-oviposition, half oviposition, and incubation periods are plotted one above the other by addition. The Graph shows that the shortest life cycle takes about 77,5 days at about 29°C. and gets longer as temperature decreases.

CONTROL

Natural enemies

Some workers in different parts of the world reported certain insects enemies for *Orthezia insignis*, as follows : Mercet (1922) reported *Chales*

noaki (Hymenoptera: Chalcididae), *Ritchi* (1934) reported *Paragus marshalli* (Diptera: Syrphidae), and *Cockerell* reported *Diplosis coccidarum* (Diptera: Cecidomyiidae).

In Egypt, some infested plants were kept at different times of the year, in a closed wooden box with five openings, each leading to a test tube. Insects that went out into the tubes were identified as follows: *Anagrus* spec. (Hymenoptera: Mymaridae), a parasite on eggs of various insects including mealybugs; *Aphelinus* spec. (Hymenoptera: Aphelinidae), an internal parasite of some insects including mealybugs; and *Orius* spec., a Hemipterous predator.

Just in one case, a spider was found feeding upon two full grown adults of *Orthezia insignis*.

Chemical control

Investigators as *Bodkin* (1916), *Golledge* (1925), *Worsley* (1936), *McIndoo* (1916), *Wallace* (1922), *Weigal* (1923), and *Schumacher* (1919), had all published their results in this respect. They tried spraying with plain water at high pressure: oils, nicotine sulphate, or an extract of *Mundulea sericea* (*suberosa*), an East African plant. Fumigation with hydrocyanic acid gas and dusting with derris were tried too.

All experiments of spraying, fumigation, or dusting in Egypt were applied in Alexandria, the only infested place in this Country.

Spraying technique was as follows:

1. Suitable infested hedges of *Clerodendron inerme*, *Lantana camara*, *Bignonia* spec., and *Ipomoea palmata*, were selected and divided into ample parts of similar conditions as much as possible. Each part was sprayed with a special insecticide of a certain concentration. Chemicals used were Citro, CS, Triona, Volck, and E 605. CS is a new product received from Dr. *Abd Allah*, a chemist in Alexandria, Egypt; E 605 is a phosphorous compound of the *Bayer Co.*, Germany; and the rest of chemicals are mineral oils.

2. The ground under the hedges was sprayed too, in order to kill the insects which might fall down due to the pressure of the spray. This treatment was also useful for killing both the insects on the bare parts of roots and those which might be present on the grass or other plants beneath the hedge.

3. Spraying was always sufficient. This required about 12 litres of the diluted spray for each cubic meter of the hedge and the ground beneath it.

4. The spray was always under the pressure of 350 pounds per square inch. The temperature varied between about 30 and 40°C., according to the time of the year.

5. Since the generations of this pest are always overlapping, and the full grown adult females are found at any time with their ovisacs containing eggs, it was necessary to repeat each experiment after about five weeks from the first

spraying, to control both the newly hatched larvae and the remaining live insects.

6. The result of each spray was taken after about two weeks from the date of the treatment.

7. Supposing that "x" is the number of the live insects before the treatment, and "y" is the number of the insects which remain live until the date of taking results, the formula used to get the percentage of killing was : $\frac{x-y}{x} \times 100 = \text{killing percentage}$. This formula has two advantages : firstly it does not require to get the percentage of natural mortality, and secondly it has nothing to do with dead insects which usually, in such and similar cases, get lost specially on windy days. Samples for counting were collected at random just before the treatment. A sufficient number of the terminal parts of the branches were taken to represent every part of the hedge going to be treated. These branches were well mixed, and five of them were randomly taken for counting. The live insects on the first three centimetres at the apex of each one of these five branches were counted, and the total addition represented "x". This step had to be repeated after two weeks in order to get "y".

8. The insecticides which did not give comparatively good results were dropped out, while promising chemicals were repeatedly applied and averages were considered as final results.

Tables listing experimental figures are eliminated here for lack of space. They show, however, that the best results for one spray are : CS 6%, 95.2% killing; followed by Volck 4%, 94.3 % killing. Then come respectively : CS 5%, 92.6 %; Citro 4%, 89.9%; Triona 4%, 78.1%; Volck 3%, 74.3%; Citro 3%, 69.8%; and Triona 3%, 58.0%

Results of the two consecutive sprays, calculated from the number of the live insects before the first spray and the number of the remaining live insects after the second spray, are as follows : The best emulsion is CS 6%, then comes Volk 4%, and finally CS 5%. According to this result, the choice between CS and Volck is only a matter of cost in case both materials are available.

Fumigating experiments were carried on by fumigating potted plants of *Hemigraphis colorata* under normal pressure, inside an iron cylinder, about 40 cubic feet in capacity. The chemicals for each fumigation consisted of 10 grams sodium cyanide, 20 cc. sulphuric acid, and 30 ml. water. This dose was tried for different periods, varying from 20 to 90 minutes. Facilities did not allow trials with different doses, mainly because infested pots were not enough and fumigating hedges was, of course, impractical. The result by the applied dosage was 100% killing for all the different exposures.

Although the *Hemigraphis* plants are tender, they were only slightly affected after having been exposed to the gas for 90 minutes; and even then, they

began to recover after two weeks of the treatment. The fumigated plants were tested nearly every two weeks, but no live insects were ever found. A result showing that fumigation with hydrocyanic acid gas for 20 to 30 minutes is the most effective control measure whenever practical; especially because it kills eggs too, since no live new hatch existed inside or outside the ovisacs of fumigated adults.

Dusting was tried just once on a hedge of *Clerodendron inerme* by applying a 5% mixture of E 605 in kaolin. The result had been so unpromising that the experiment was not repeated (only 40.7% killing).

SUMMARY

Orthezia insignis Browne is a destructive pest, liable to be more serious in Egypt if got the chance to attack those crops of major economic importance which it had already attacked in other Countries.

From its distribution, it appears that this pest in the plain is rather confined to islands, shores, or areas with high amount of rainfall, a condition suggesting that the penetration of this insect inside Egypt is fairly limited. This being the case, the olive trees of Burg El-Arab, *Citrus* trees, vegetables and other plants in the northern parts of the Nile Delta are the crops to be protected from any further spread of this pest.

Since the highest zero of development is about 14°C. (for the adult female), this degree is considered to be the lowest critical temperature for *O. insignis*. On the other hand, it was noticed that the majority of dead eggs had passed through an average temperature of about 34°C during their incubation period, although no other stage was seriously affected by a temperature as high as this. Therefore, the highest critical temperature is probably around this degree though distribution suggests that humidity might help in overcoming higher temperatures. Inside greenhouses, temperature is not a limiting factor for a continuous development.

Control is best achieved through fumigation with hydrocyanic acid gas whenever applicable, that is particularly in greenhouses. Otherwise, two successive sprays at an interval of 5 weeks with Volck 4%, CS 5-6%, or Citro 4% will do as well.

LITERATURE

- Alfieri, A. (1929) : Le principaux insectes nuisibles infectant le jardin de Nouzha (*Bull. Soc. Roy. Ent. Egypte*, XIII, pp. 7-8).
- Bodkin, G. E. (1913) : Insects injurious to sugar-cane in British Guiana, and their natural enemies (Board of Agric. Brit. Guiana, VII, No. 1, pp. 29-32).

- Bodkin, G. E. (1916) : Report of the Economic Biologist (Rept. Dept. Sci. and Agric. Brit. Guiana, for the nine months ended 31st December 1915, 10 pp.).
- Bordage, E. (1914) : Biological notes from Réunion (*Bull. Scient. France et Belgique*, Paris, XIVII, No. 4, pp. 377-412, 14 figs).
- Gollidge, G. J. (1915) : The insects injurious to chrysanthemums in Britain (*Journ. North England Hortic. Soc.* (Leeds), Nos. 53-54, pp. 205-216).
- Green, E. E. (1922) : The *Coccidae* of Ceylon, V (pp. 418-421).
- James, H. C. (1939) : Further studies on the reproductive methods of certain species of *Coccidae* [Homoptera] (*Trans. R. Ent. Soc.*, LXXXIX, pt. 12, pp. 569-577).
- Kunhi Kannan, K. (1920) : The life-history of *Orthezia insignis* (Rept. Proc. 3rd Ent. Meeting [Calcutta], III, pp. 852-858).
- Mercet, R. G. (1922) : Notas sobre Afelinidos (Hym. Chalc.), 20a nota (*Eos*, V, No. 1, pp. 111-116).
- McIndoo, M. E. (1916) : Effects of nicotine as an insecticide (*Journal Agric. Res.*, VII, No. 3, pp. 89-122, 3 plates).
- Morrison, H. (1925) : Classification of scale insects of the subfamily *Ortheziinae* (*Journal Agric. Res.*, XXX, No. 2).
- Morrison, H. (1928) : A classification of the higher groups and genera of the coccid family *Margarodidae* (*Tech. Bull. U. S. Dept. Agric.*, No. 52).
- Morrison, H. (1952) : Classification of the *Ortheziidae* (*Tech. Bull. U. S. Dept. Agric.*, No. 1052).
- Pinkey, E. C. (1945) : *Orthezia* bug (*Rhod. Agr. Journal*, XLII, No. 1, pp. 24-30).
- Ramachandra Rao, Y. (1920) : *Lantana* insects in India report on an inquiry into the efficiency of indigenous insect pests as a check on the spread of *Lantana* in India (Entom. Ser. V, No. 6, pp. 239-314, 14 plates, Pusa).
- Ritchie, A. H. (1934) : Report of the Entomologist (Rep. Dept. Agric. Tanganyika, pp. 73-83).
- Salmon de los Heros, A. (1933) : Three insects dangerous to fruit-growing and gardening : *Aulacaspis pentagona*, *I. purchasi*, and coccids of the genus *Orthezia* (*Bol. Direc. Agric. Ganad. Peru*, III, Nos. 11-12, pp. 467-481).
- Schumacher, F. (1919) : Entomologisches aus dem Botanischen Garten zu Berlin-Dahlem. i, *Orthezia insignis* Douglas (*Sitz. Ges. Natur. Freunde*, Berlin, Nos. 9-10, pp. 379-384).
- Severin, H. C. (1924) : Insect and other enemies harmful to greenhouse plants (15th Ann. Rept. State Ent. S. Dakota, pp. 10-63, 24 figs).
- Subramania, T. V. (1932) : Annual Report of the Entomological Section for 1930-31 (Mysore Agric. Dept., pp. 28-32).

- W a l l a c e , F. N., and others (1922) : Report of the Division of Entomology (3rd Ann. Rept. Indiana Dept. Conservation, pp. 37-57).
- W e i g e l , C. A. (1923) : Insect enemies of chrysanthemums (*Farmers' Bull.*, (U.S. Dept. Agric., No. 1306).
- W o r s l e y , R. R. (1936) : The insecticidal properties of some East African Plants. II, *Mundulea suberosa* Benth. (*Ann. Appl. Biol.*, XXIII, No. 2, pp. 311-328, 6 figs).
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The Genus *Brevipalpus* in Egypt

[Acarina : Tenuipalpidae]

(with 45 Text - Figures)

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Sayed (1950) created the family Tenuipalpidae to include the genera *Brevipalpus* (Donnadieu, 1875), *Tenuipalpus* (Donnadieu, 1875), *Phytoptipalpus* (Tragardh, 1905), *Pseudoleptus* (Bruyant, 1911), *Raoiella* (Hirst, 1924), *Phyllotetranychus* (Sayed, 1938), *Dolichotetranychus* (Sayed, 1938), *Tegopalpus* (Womersely, 1940) and *Aegyptobia* (Sayed, 1950),

Pritchard and Baker (1951), considering the type genus of the family to be the genus that was first used as supra-generic name, stated that the name of the family has to be *Phytoptipalpidae* (Ewing, 1922). The writer agrees with Sayed, that *Phytoptipalpus*, which has only three pairs of legs in the adult stage, cannot be the type genus. Moreover, the writer is inclined to leave the genus *Phytoptipalpus* in its old family *Phytoptipalpidae*, which should include also the genus *Larvacarus* (Baker and Pritchard, 1952). Though these two genera are quite related to the genera of the family Tenuipalpidae, yet, the suppression of one pair of legs, in the adult stage, is a sharp deviation in the order Acarina and thus justifies this separation.

The genus *Brevipalpus* was considered to be a synonym of the genus *Tenuipalpus*; on this basis, Sayed (1942) redescribed three mites: *Tenuipalpus oudemansi* Geijskes, *Tenuipalpus obovatus* Donnadieu, and *Tenuipalpus orchidarum* Parfitt, from Egypt. Later on, the two genera were separated, and consequently Sayed (1946) changed the names of the first two mites which fall in the genus *Brevipalpus* into *Brevipalpus pyri* Sayed and *Brevipalpus obovatus* Donnadieu. Sayed (1950) described a third species, *Brevipalpus olearius*, found on olive trees. Baker (1949) considered the mite recorded and redescribed by Sayed as *Brevipalpus obovatus*, a new species, and gave it the name *Brevipalpus browni*gi. However, Pritchard and Baker

(1951) considered *Brevipalpus browningi* to be synonym of *Brevipalpus australis* Tucker. Baker and Pritchard (1952) divided the genus *Brevipalpus* into two major groups: the *geisenheyneri*-group which contains species that possess a seta on the hysterosoma between the first dorso-central and the humeral setae (Fig. A), and the *inornatus*-group which contains species that lack such seta; they considered *Brevipalpus pyri* Sayed to be synonym of *Brevipalpus geisenheyneri* Ruebsaamen.

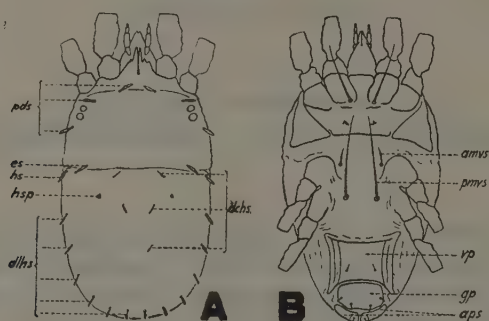


Fig. A: Dorsal aspect of a *Brevipalpus* mite (*dlhs*, dorso-central hysterosomals; *dlhs*, dorso-lateral hysterosomals; *es*, extra seta; *hs*, humeral seta; *hsp*, hysterosomal pore; *pds*, propodosomals). — Fig. B: Ventral aspect of a *Brevipalpus* mite (*amvs*, anterior medio-ventral seta; *aps*, anal plates; *gp*, genital plate; *pmvs*, posterior medio-ventral seta; *vp*, ventral plate).

In this paper, a new species from Egypt is described, three other species of the genus are re-described, and previously recorded species are briefly considered. The nymphs of *Brevipalpus lanceolatisetae* nov. spec., *Brevipalpus geisenheyneri* and *Brevipalpus olearius* are also described, and the nymphs of all the other Egyptian species are described. All the nymphs were found associated with adults and no breeding was done. Keys to females and nymphs are given. As to males, many of them have not yet been found in Egypt. Key of nymphs is based on relative lengths and shapes of marginal body setae; as these characters vary in some species, the key is based on characters found in the majority of specimens examined in every species.

The legs of all species of the genus *Brevipalpus* in Egypt have a rather constant setal pattern. Tarsi I and II (Figs. 7 and 8), dorsally, have two hairs, one long medial, the other shorter, external; laterally, they bear two pointed hairs; and ventrally, there are two external feather-like setae, and two internal blunt ones with prominent bases. Moreover, tarsus I has always one rod-like seta dorso distally, tarsus II has either one (Fig. 41) or two (Fig. 28), tarsi III and IV have neither dorsal sensory rods, nor ventral

blunt setae. Each claw has a basal projection provided with one pair of outer long tenent hairs and a row of shorter inner ones; the empodium has two rows of short tenent hairs. Sensory rods of the species of the *geisenheyneri*-group are long and reach the end of the tenent hairs in the female (Figs. 7 and 8), and are much longer in the male, while these rods are short in all Egyptian species of the *inornatus*-group (Figs. 28 and 41). The number of sensory rods of tarsus II in the male may differ from that of the female of the same species; in *Brevipalpus oelarius*, the female has one rod, while the male has two. Pritchard and Baker (1951) stated: "A specimen very rarely may be found that possesses an extra sensory peg on tarsus II on one or both legs, even though it represents a species that is characterized by having only one such rod on this segment". The writer has found a sole specimen of *Brevipalpus inornatus* in which tarsus II of one leg has one sensory rod, while the other has two.

Key to Egyptian species

Females

1. Front and rear mite broadly rounded; extra seta between humeral and first dorso-central hysterosomal seta present; rods of tarsi I and II long, reaching to distal end of tenent hairs (*geisenheyneri*-group)..... 2
- Hysterosoma with lateral margins subparallel, converging posteriorly; no extra seta between humeral and first dorso-central hysterosomal seta; rods of tarsi I and II short (*inornatus*-group)3
2. Marginal setae of body and extra seta broadly lanceolate, serrate; dorsal seta of each of femur I and II broadly lanceolate serrate.....
..... ***Brevipalpus lanceolatisetae* nov. spec.**
- Marginal setae of body and extra seta tapering, plumose; dorsal seta of each of femur I and II setiform.....
..... ***Brevipalpus geisenheyneri* Ruebsaamen (pyri Sayed)**
3. Hysterosoma with five dorso-laterals (and one humeral)4
- Hysterosoma with six dorso-laterals (and one humeral).....5
4. Tarsus II with one sensory rod; propodosoma with medio-lateral reticulate pattern, elements little longer than wide; no striations medio-dorsally ...
..... ***Brevipalpus inornatus* Banks**
- Tarsus II with two sensory rods; propodosoma with medio-lateral reticulate pattern, elements much longer than wide; irregular striae medio-dorsally **(*Brevipalpus phoenicis* Geijskes)**
5. Tarsus II with one sensory rod. 6
- Tarsus II with two sensory rods; reticulate pattern covers almost entire surface of propodosoma ***Brevipalpus australis* Tucker**

6. Rostrum elongate reaching almost to distal end of patella I.....
 **Brevipalpus olearius** Sayed
 — Rostrum not elongate, reaching a little beyond the middle of femur I
 **Brevipalpus lewisi** McGregor

N y m p h s

1. Extra seta between humeral and first dorso-central hysterosomal setae present (*geisenheyneri*-group) 2
 — No extra seta between humeral and first dorso-central hysterosomal setae (*inornatus*-group) 3
 2. Marginal setae of body and extra seta broadly lanceolate, serrate, all long except the last dorso-lateral hysterosomal much short
 **Brevipalpus lanceolatisetae** nov. spec.
 — Marginal setae of body and extra seta tapering; extra seta and dorso-lateral hysterosomals 3, 5, 6 minute, rest of marginal setae long
 **Brevipalpus geisenheyneri**
 3. Hysterosoma with five dorso-laterals (and one humeral).....4
 — Hysterosoma with six dorso-laterals (and one humeral).....5
 4. All marginal setae of propodosoma and hysterosoma about same length (sometimes humeral or first dorso-lateral hysterosomal shorter than others)
 **Brevipalpus phoenicis**
 — Marginal setae are not same in length; first propodosomal usually much shorter than second and third; humeral, first and second hysterosomals are shorter than the three last hysterosomals **Brevipalpus inornatus**
 5. Dorso-lateral hysterosomals 3, 4, 5, 6 all long, about same length 6
 — Dorso-lateral hysterosomals 3, 4, 5, 6 not same in length, seta 4 much longer than the rest **Brevipalpus olearius**
 6. First propodosomal minute.....**Brevipalpus lewisi**
 — First propodosomal long, narrowly lanceolate...**Brevipalpus australis**

Brevipalpus lanceolatisetae nov. spec.

(Figs. 1-11)

F e m a l e : 330 μ long including rostrum, 167 μ broad, shape broadly elliptical, colour bright red when alive. Rostrum long, reaching past distal end of femur I; palpus (Fig. 4) slender, dorsal seta of segment II short, about half the length of the segment, terminal segment with three pointed setae. Leg I and leg II each, with dorsal seta of femur, patella and of tibia lanceolate, serrate, that of femur long, much longer than width of segment; dorso-lateral internal seta of femur I (Fig. 3) and of femur II and ventro-lateral external seta of femur II (Fig. 2) also lanceolate, serrate; tarsi I and II each with a single sensory long rod, reaching to the end of the tenent hairs

(Figs. 7 and 8); claw with hook well developed. Rostral shield (Fig. 3) bifurcate, irregularly reticulate. Propodosoma almost entirely reticulate, medial elements larger in size than medio-lateral ones; propodosomals broadly lanceolate, strongly serrate, long, decreasing in length posteriorly. Hysterosoma above with antero-median area reticulate and postero-median area with transverse elements, medio-lateral reticulations tend to be longer than wide, lateral reticulations tend to be in bands directed towards the margin; these lateral reticulations are distinct in unboiled specimens, but they are faint in clear old

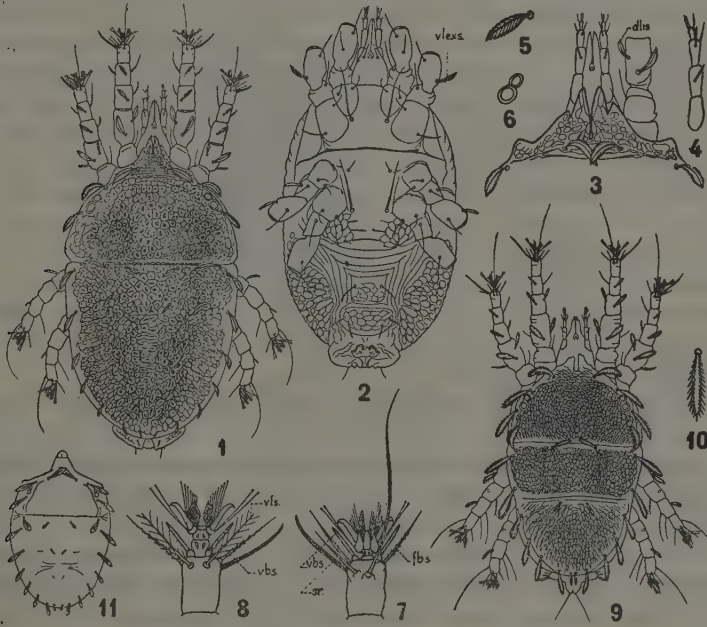


Fig. 1.: *Brevipalpus lanceolatisetae*, dorsal aspect. — Fig. 2.: *Brevipalpus lanceolatisetae*, ♀, ventral aspect (*vlexs*, ventro-lateral external seta). — Fig. 3.: Anterior of mite showing rostral shield with two first propodosomals, rostrum, palpi, a part of leg I (*dis*, dorso-lateral internal seta). — Fig. 4.: Palpus. — Fig. 5.: Propodosomal seta. — Fig. 6.: Eyes. — Fig. 7.: Tarsus of leg II, left, dorsal aspect (*sr*, sensory rod; *ls*, lateral seta; *vbs*, ventral blunt seta). — Fig. 8.: Tarsus of leg II, left, ventral aspect (*vfs*, ventral feather seta; *vbs*, ventral blunt seta). — Fig. 9.: *Brevipalpus lanceolatisetae*, ♂, dorsal aspect. — Fig. 10.: Body seta. — Fig. 11.: *Brevipalpus lanceolatisetae*, nymph, outline of body, dorsal.

prepared specimens, giving an aspect of lateral sinuous lines directed towards the margin; hysterosomal pores present but faint; dorso-lateral hysterosomals six pairs similar to propodosomals and also decreasing in length posteriorly; dorso-centrals narrowly lanceolate, serrate; extra seta longer than humeral and first dorso-central. Ventrally (Fig. 2), metapodosoma with anterior pair

of medio-central setae short, and posterior pair long; ventral and genital plates and area laterad reticulate, area anterior to ventral plate reticulate laterally and with cross faint lines medially (Fig. 2).

Male (Fig. 9) : 263 μ long including rostrum, 130 μ broad, shape oval, colour red when alive. Rostrum reaching till end of femur I; palpus slender, similar to that of female. Leg I and leg II, each with dorsal seta on femur patella and tibia lanceolate, deeply serrate; dorso-lateral internal seta of femur I and femur II also lanceolate, serrate. Propodosoma reticulate, elements are of different irregular shapes and sizes, propodosomals evidently long, lanceolate, deeply serrate and plumose (Fig. 10). Hysterosoma with a constricting line between metapodosoma and opisthosoma, reticulations similar to those on propodosoma, but the lateral elements on opisthosoma tend to be in parallel lines directed towards the margin; humeral and dorso-lateral hysterosomals similar to propodosomals, all long except the last pair; extra seta as well as dorso-centrals also lanceolate, deeply serrate.

Brevipalpus natalensis Lawrence is reported from South Africa. Baker (1949), and Pritchard and Baker (1951), stated that Lawrence (1943) has only illustrated the male. Propodosomals of *Brevipalpus natalensis*, as illustrated by Lawrence (1943), are much shorter than those of *Brevipalpus lanceolatisetae* : rostrum reaches only till half of femur I, marginal setae of hysterosoma are figured as six pairs only (one humeral and five dorso-laterals) and dorso-centrals as two pairs.

Nymph (Fig. 11) : Extra seta between humeral and first dorso-central setae, present, similar to propodosomals and dorso-lateral hysterosomals, broad, lanceolate and serrate; propodosomals about equal in length, hysterosomals decrease in length posteriorly, but the last pair is much shorter than the rest.

Host plants : *Prunus domestica* (prunes), *Prunus armeniaca* (apricots), *Pyrus communis* (pears), and *Pyrus malus* (apples), in Lower and Upper Egypt.

***Brevipalpus geisenheyneri* Ruebsaamen**

(= *Brevipalpus pyri* Sayed)

(Figs. 12 and 13)

Female (Fig. 12) : The female of *Brevipalpus geisenheyneri* differs from that of *Brevipalpus lanceolatisetae* in the dorsal setae of body which are all tapering, plumose; dorsal seta of femora, patella and of tibia is setiform, plumose. Rostrum shorter than that of *Brevipalpus lanceolatisetae*, reaching only to the half, and in some specimens hardly to the end of femur I.

Sayed (1946) differentiated *Brevipalpus pyri* from *Tenuipalpus oudemansi* on account of the two posterior medio-ventral setae which are illustrated short in the drawings of Geijskes (1939), while they are long in *Brevipalpus*

pyri. Baker and Pritchard (1952), in their re-description of *Brevipalpus geisenheyneri*, stated : "Nearly all the European material studied agrees with the drawings (Sayed, 1946) of *pyri* that were based on type specimens from Egypt. The drawings (Geijskes, 1939) of *oudemansi* that were based on type specimens from Holland differ only in indicating the dorsal setae of the body somewhat shorter and the medio-ventral metapodosomals all similar in length; these differences are probably due to differences in illustrating techniques".

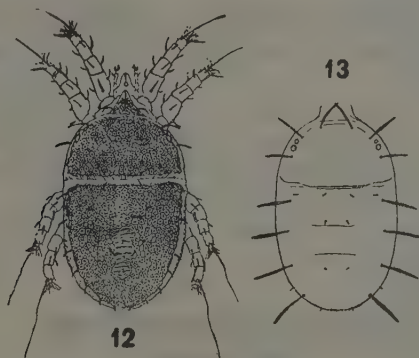


Fig. 12 : *Brevipalpus geisenheyneri*, ♀ (= *Brevipalpus pyri* Sayed), figure after Sayed (1942). — Fig. 13 : *Brevipalpus geisenheyneri*, nymph, outline of body, dorsal.

The dorsal reticulations of *pyri* and of *oudemansi* are evenly spaced, while the dorsal reticulations of *geisenheyneri*, as illustrated by Ruebsaamen (1910) in specimens from Germany, degenerate in sinuous lines on the lateral sides of the body.

In spite of this difference, Baker and Pritchard (1952), according to their observations on specimens from Israel, confirm that they are all but one species. The dorsal reticulations in these latter specimens were either tortuous, partially irregular, or evenly spaced. Reticulations in specimens from Europe were evenly spaced, while the specimens from Afghanistan, were typical with *geisenheyneri*. André (1954) stated that all the specimens examined from Algeria agree with the drawings of Geijskes and Sayed ; none of the individuals showed an intermediary aspect between the figures given by Geijskes, Sayed and those given by Ruebsaamen, Baker and Pritchard. At the most, the polygons which adorn the dorso-lateral surfaces form, by their connection, continuous lateral bands resembling but very little the aspect given by Ruebsaamen. He also stated that, if we consider that the drawings of Ruebsaamen are precise, we should have to admit that his species shows a variety which might

be distinguished from the typical form on account of the regularity of its dorsal reticulations; to affirm this fact he will wait for the occasion to study samples from Israel from where Baker and Pritchard had specimens of variable dorsal ornamentation.

The writer has examined specimens from Egypt, Libanon and Turhey; the reticulations on the lateral sides of the body are existing, forming tortuous bands directed towards the margin; but in clear preparations, these reticulations become faint giving the aspect of sinuous lines directed towards the margin.

Male : Dorsal body setae elongate, tapering, and plumose; dorsal seta on each of femora, patella, and tibia, setiform. Rostrum short, reaching to the half of femur I.

Nymph (Fig. 13) : Extra seta between humeral and first dorso-central hysterosomal setae present; all dorsal body setae tapering; propodosomals, humeral and dorso-lateral hysterosomals 1, 2, 4 long, about equal; extra seta and dorso-lateral hysterosomals 3, 5, 6 minute.

Host plants : Sayed (1942), reported it on apples, pears, plums, apricots and other trees.

Brevipalpus inornatus Banks

(Figs. 14-21)

Female : 302 μ long, 150 μ broad. Rostrum short, not reaching middle of femur I; palpus (Fig. 17) with segment II has a sharp inner basal swelking and a dorsal lanceolate and serrate seta, terminal segment with two setae and one sensory rod. Tarsus II with one sensory peg; dorsal seta of femur I (Fig. 18) and of femur II lanceolate, serrate, almost half as long as width of segment. Propodosoma with dorsal reticulations not meeting medially (Fig. 14), elements little longer than wide, propodosomals short, lanceolate, serrate. Hysterosoma medially, with dorsal irregular striations, medio-laterally, with reticulate elements longer than wide, and laterally with longitudinal striations directed towards margin; dorso-lateral hysterosomals five pairs lanceolate, serrate; hysterosomal pores present but weakly indicated. Reticulate elements of genital and ventral plates wider than long; area anterior to ventral plate with such reticulations extending till medio-ventral posterior setae in some specimens and beyond them in others; medio-ventral posterior setae do not reach the suture between propodosoma and hysterosoma (but hardly reach the suture in some specimens).

Male (Fig. 20), after Pritchard and Baker (1951) : The male has not yet been found in Egypt; these authors state that it has the main characters of the female.

Nymph (Fig. 21) : Hysterosoma with five dorso-laterals on each

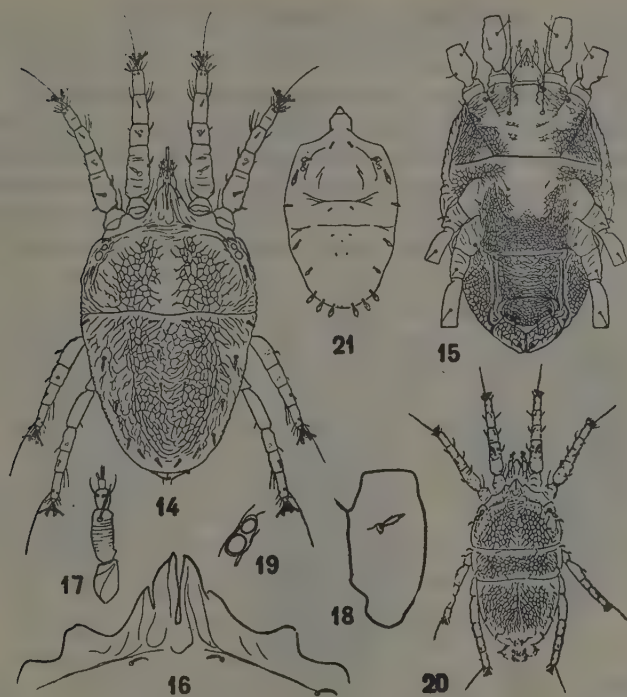


Fig. 14: *Brevipalpus inornatus*, ♀, dorsal aspect. — Fig. 15: *Brevipalpus inornatus*, ♀, ventral aspect. — Fig. 16: Rostral shield with first two propodosomals. — Fig. 17: Palpus. — Fig. 18: Femur I, right, dorsal aspect. — Fig. 19: Eyes. — Fig. 20: *Brevipalpus inornatus*, ♂, dorsal aspect (figure after Pritchard and Baker, 1951). — Fig. 21: *Brevipalpus inornatus*, nymph, outline of body, dorsal.

side ; first propodosomal usually minute, much shorter than all marginal body setae; second and third propodosomals long, usually the third being longer and about as long as the last three dorso-lateral hysterosomals; humeral and first two dorso-lateral hysterosomals short, about the same length, but the first dorso-lateral usually little longer; the last three dorso-lateral hysterosomals always long, the longest of all marginal setae. In some specimens first propodosomal reaches about as long as the second; the second propodosomal may be about as long as the third; humeral and first two dorso-lateral hysterosomals may be as long as the second propodosomal. All marginal body setae lanceolate, serrate.

Host plants : *Pyrus communis*, *Pyrus cydonia*, some ornamental plants as *Populus deltoidea*, *Geranium* sp., *Euphorbia* sp., *Buddleia* sp., and on weeds as *Plantago major*.

***Brevipalpus phoenicis* (Geijskes)**

(Figs. 22-31)

Female: 300 μ long (including rostrum), 147 μ broad. Rostrum reaches past middle of femur I; palpus (Fig. 26) with very slight inner basal swelling in segment II, dorsal setae of segments II and III slender, serrate; apical segment with one sensory peg and two setae of which one is stout. Tarsus II with two sensory rods; femur I (Fig. 27) and femur II each with dorsal seta broadly lanceolate, serrate, about three fourths as long as width

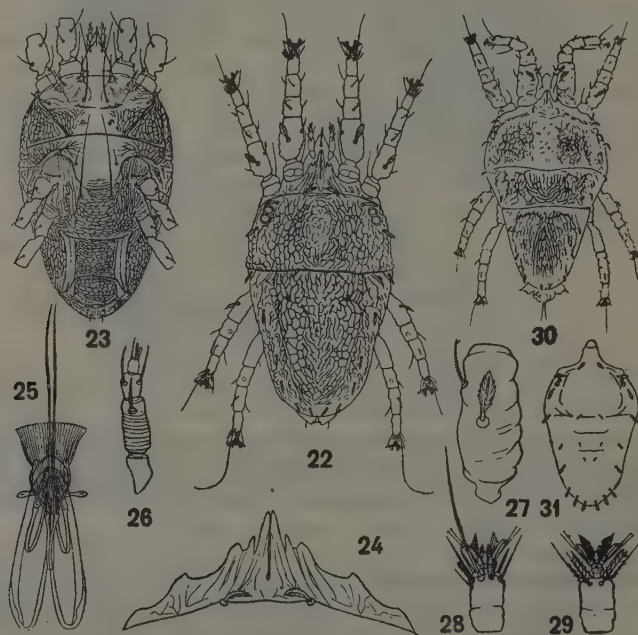


Fig. 22: *Brevipalpus phoenicis*, ♀, dorsal aspect. — Fig. 23: *Brevipalpus phoenicis*, ♀, ventral aspect. — Fig. 24: Rostral shield. — Fig. 25: Breathing apparatus. — Fig. 26: Palpus. — Fig. 27: Femur I, right, dorsal. — Fig. 28: Tarsus II, left, dorsal. — Fig. 29: Tarsus II, ventral. — Fig. 30: *Brevipalpus phoenicis*, ♀, dorsal (figure after Pritchard and Baker, 1951). — Fig. 31: *Brevipalpus phoenicis*, nymph.

of segment; dorso-lateral internal seta slender, serrate. Propodosoma with medio-dorsal irregular striae, medio-lateral longitudinal reticulations and lateral irregular striations; propodosomals relatively long, lanceolate, serrate. Hysterosoma with medio-dorsal irregular striae, medio-lateral reticulations with elements longer than wide and lateral irregular striations; hysterosomal

pores present, more evident in some specimens than in others; dorso-lateral hysterosomals five pairs, lanceolate, serrate, little shorter than propodosomals; dorso-centrals slightly lanceolate, serrate. Genital and ventral plates reticulate, elements wider than long; area anterior to ventral plate with similar reticulations extending beyond medio-ventral posterior setae; reticulate elements in other plates longer than wide, medio-ventral posterior setae long, surpassing suture between propodosoma and hysterosoma.

Male (Fig. 30), after Pritchard and Baker (1951): This sex has not yet been found in Egypt; Pritchard and Baker (1951) state: "The male of *phoenicis* (from Florida on Citrus), previously unknown, is similar to the female in the dorsal integumentary pattern of the propodosoma. The dorsum of the metapodosoma is irregularly striate medially and reticulate medio-laterally. The episthosoma bears long reticulations dorsally and it is evenly areolate ventrally".

Nymph (Fig. 31): Hysterosoma with five dorso-laterals; all marginal body setae lanceolate, serrate, about the same length; first dorso-lateral, or humeral seta, may be shorter than other marginal setae; in some specimens first propodosomal is the shortest of all.

Host plants: *Pyrus communis*, *Pyrus cydonia*, *Vitis viniferae*, some ornamental plants as *Pittosporum tobira*, *Buddleia* sp., and *Clerodendrum inerme*.

***Brevipalpus australis* Tucker**

(Figs. 32 and 33)

Female: The rostrum reaches till half of femur I. Tarsus II with two sensory rods; dorsal seta of femur I and femur II narrowly lanceolate, serrate, longer than half the width of segment. Propodosoma reticulate,

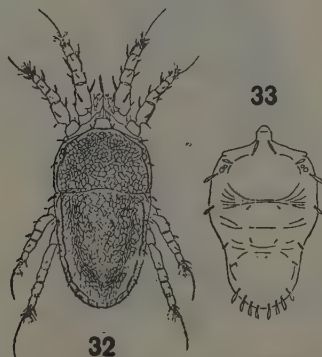


Fig. 32: *Brevipalpus australis*, ♀, dorsal. — Fig. 33: *Brevipalpus australis*, nymph, outline of body, dorsal.

reticulations medio-dorsally sometimes irregular. Hysterosomal pores present.

Male : Characters of the female together with having elongate reticulations medio-laterally on the opisthosoma and metapodosoma.

Nymph (Fig. 33) : Hysterosoma with six dorso-laterals; first propodosomal long, about equal to last four dorso-lateral hysterosomals; second and third propodosomals shorter than the first (usually the second little shorter than the third); first and second dorso-lateral hysterosomals are the shortest of all marginal setae; humeral varies from shorter to as long as second propodosomal.

Host plants : Sayed (1942), reported it on citrus, guava, plums and apricots; the writer found it also on vine and some ornamental plants as *Dolichos lablab*.

***Brevipalpus olearius* Sayed**

(Figs. 34 and 35)

Female (Fig. 34), after Sayed (1950) : Rostrum long, reaching almost till distal end of patella I. Tarsus II with one sensory rod. Hysterosoma with six dorso-laterals.

Male : Rostrum reaches past distal end of femur I. Tarsus II unlike the female, with two sensory rods.

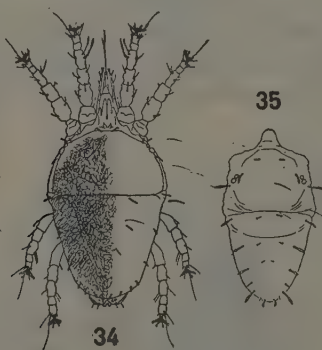


Fig. 34 : *Brevipalpus olearius*, ♀, dorsal aspect (figure after Sayed , 1950). — Fig. 35 : *Brevipalpus olearius*, nymph, outline of body, dorsal.

Nymph (Fig. 35) : Hysterosoma with six dorso-laterals; first propodosomal minute, about equal to third and fifth dorso-lateral hysterosomals; third propodosomal and fourth dorso-lateral hysterosomal about the same

length, and the longest of all marginal setae; the rest of marginal setae are medium and about the same length.

Host plants : Olive trees.

***Brevipalpus lewisi* McGregor**

(Figs. 36-43)

Female : 290 μ long (including rostrum), 150 μ broad. Rostrum broadly triangular, reaching a little beyond the middle of femur I, palpus (Fig. 38) normal, terminal segment with two setae and one rod. Tarsus II with one sensory peg; dorsal seta of femur I (Fig. 40) and of femur II lanceolate, serrate, about half as long as width of segment; ventro-lateral external seta of femur II (Fig. 37) clearly lanceolate, serrate. Propodosoma with medio-dorsal irregular striae, medio-lateral longitudinal reticulations and lateral striations; propodosomals short, slightly lanceolate, serrate. Hysterosoma with medio-dorsal irregular striations, medio-lateral longitudinal reticulations and lateral longitudinal striae directed towards the margin;

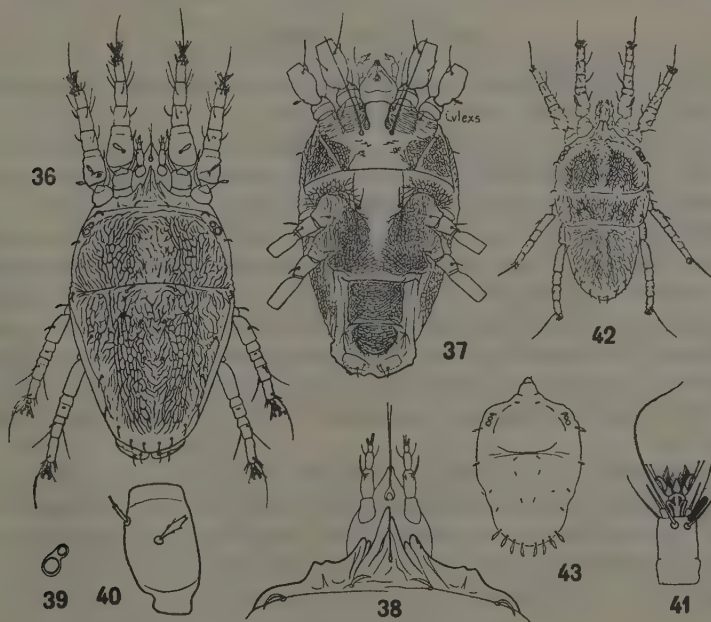


Fig. 36 : *Brevipalpus lewisi*, ♀, dorsal aspect. — Fig. 37 : *Brevipalpus lewisi*, ♀, ventral aspect (vlexs, ventro-lateral external seta). — Fig. 38 : Rostral shield and rostrum with palpi. — Fig. 39 : Eyes. — Fig. 40 : Femur I, right. — Fig. 41 : Tarsus II, right, dorsal. — Fig. 42 : *Brevipalpus lewisi*, ♂, dorsal (after Pritchard and Baker, 1951). — Fig. 43 : *Brevipalpus lewisi*, nymph, outline of body, dorsal.

dorso-lateral hysterosomals six pairs slightly lanceolate (do not appear so in some specimens), serrate; hysterosomal pores strongly tubular. Reticulate elements of genital and ventral plate (Fig. 37) wider than long; such reticulations extend anterior to ventral plate, but the area between the posterior medio-ventral setae is plain; posterior medio-ventral setae hardly reach the suture between propodosoma and hysterosoma, but are shorter in some specimens.

Male (Fig. 41), after Pritchard and Baker (1951): The male is not yet seen in Egypt; Pritchard and Baker state that it has the characters of the female, and that the medio-ventral setae of the opisthosoma are located behind the middle of this segment.

Nymph (Fig. 42): Hysterosoma with six dorso-laterals; first propodosomal and first two dorso-lateral hysterosomals equal, minute; second propodosomal and humeral equal, and shorter than third propodosomal; last four dorso-lateral hysterosomals about the same length and the longest of all marginal setae.

Host plants: *Vitis vinifera* (vine).

MOUNTING MEDIA

Keifer (1953) recommended the following formulae as a mounting media for Tetranychid and Tyroglyphid mites:

The preparatory medium: (1) melted phenol 4 cc.; (2) lactic acid solution, 12 cc.; (3) resorcinol, 1/2 gram (or less); (4) potassium iodide, 1/2 gram; (5) hydrochloric acid solution concentrate, 16 drops.

Heat the mites in a portion of this solution until the desired clarity is attained. Allow to cool and add some standard formaldehyde solution. Allow to stand for at least half an hour. The formaldehyde sets the specimens and they will not lose shape when transferred to the permanent medium, which is: (1) gum arabic, 1 gram; (2) table sugar, 1 gram; (3) chloral hydrate, 10 grams (or more); (4) potassium iodide crystals, 1/2 gram; (5) iodine crystals, 1/2 gram (or less); (6) glycerin, 2 cc.; (7) formaldehyde, one half strength, 1-3 cc.

The writer tried the previous method in mounting *Brevipalpus* species; the preparatory medium was not suitable for attaining sufficient clarity because the specimens were destroyed by long heating; the writer tried increasing the amount of lactic acid to 18 cc., and the satisfactory results were obtained.

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BIBLIOGRAPHY

- André, M. (1953) : Acariens Phytoptipidae parasites des Orchidées, Cactées et plantes grasses cultivées en serres. 1. *Tenuipalpus orchidarum* Parfitt (*Bull. Mus. National Hist. Natur.*, 2e série, XXV, No. 5, Paris).
- André, M. (1954) : *Brevipalpus geisenheyneri* (Ruebsaamen), acarien parasite des arbres fruitiers (*Bull. Mus. National Hist. Natur.*, 2e série, XXVI, No. 3, Paris).
- Baker, E. W. (1949) : The Genus *Brevipalpus* [Acarina : Pseudoleptidae] (*The American Midland Naturalist*, XLII, No. 2).
- Baker, E. W., and Pritchard, A. E. (1952) : The *Geisenheyneri* species Group of the Genus *Brevipalpus* [Acarina : Phytoptipalidae] (*Annals Mag. Natur. History*, Ser. 12, V, p. 609).
- Geijskes, D. (1939) : Beitrage zur Kenntnis der Europäischen Spinmilben [Acari, Tetranychidae], mit Besonderer Berücksichtigung der Niederländischen Arten (*Med. Landbouwhoogeschool*, XLII (4), pp. 23-24, fig. 7, Wageningen, Nederland).
- Keifer, H. H. (1953) : Eriophyid Studies, XXI (*Bull. Dept. Agric. State California*, XLII, No. 2).
- Lawrence, R. F. (1943) : New South African Mites of the Genus *Tenuipalpus* Donnadieu [Tetranychidae] (*Trans. Royal Soc. South Africa*, XXX (1), Cape Town).
- Pritchard, A. E., and Baker, E. W. (1951) : The false spider mites of California [Acarina : Phytoptipalidae] (*Univer. Calif. public. Entom.*, IX, No. 1, pp. 1-94).
- Ruebsaamen, E. H. (1910) : *Tenuipalpus geisenheyneri* (*Zeits. Wiss. Insectenbiologie*, VI, p. 127).
- Sayed, M. T. (1942) : Contribution to the knowledge of the Acarina of Egypt : II. The Genus *Tenuipalpus* Donnadieu [Tetranychidae] (*Bull. Soc. Fouad Ier Ent.*, XXVI).
- Sayed, M. T. (1946) : Description of *Tenuipalpus granati* nov. spec. and *Brevipalpus pyri* nov. spec. [Acarina : Trichadenidae] (*Bull. Soc. Fouad Ier Entom.*, XXX).
- Sayed, M. T. (1950) : Description of a New Genus and two New Species of the Family Tenuipalpidae Sayed [Acarina] (*Proc. 8th. Intern. Congress Entom.*, Stockholm).

- Sayed, M.T. (1950) : On the Taxonomy of Tetranychid and allied Genera.
A new Family and two new sub-Families in Acarina (*Proc. 8th. Intern.
Congress Entom.*, Stockholm).
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The economic importance of mites affecting fruit trees, with special reference to Citrus, in Egypt

[Acarina]

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The Tenuipalpidae, Eriophyidae and Tetranychidae cause extensive damage to deciduous and evergreen fruit trees (apples, pears, peaches, apricots, almonds, plums, figs, etc.), causing leaf drop, their general effect being to weaken the tree, check its growth and lower its productivity. Of late, such damage has increased to injurious levels and new records, viz. :

The European Red Mite, *Paratetranychus pilosus* (Canestrini and Fanzago), has recently been recorded attacking pears in Samanud (Gharbieh Province) ⁽¹⁾.

The Mango is seriously attacked by the bud mite, *Aceria mangiferae* ⁽²⁾, which threatens the very existence of mango culture in Egypt.

Citrus trees are attacked by various species belonging to the above families.

Hall ⁽³⁾ referred to the damage done by Rust or Silver mites in Egypt about thirty years ago.

On account of their small size mites are apt to escape the notice of growers; a trained observer, however, cannot fail to see the symptoms of attack. Mites feed on fruit, leaves and green twigs of citrus, thus greatly reducing the tree vigour. They are most abundant on new growth and cause fruit drop by

⁽¹⁾ Journal Officiel, No. 98 (9. xi. 1954), page 13. — (Immature stages of the mite were first intercepted by Dr. Taher Sayed, in 1948. The were found on pear twigs from the farm of Kut El-Kolub, near Benha. The sticks were imported from the Mediterranean area).

⁽²⁾ Taher Sayed, M.: *Aceria mangiferae*, nov. spec. (*Eriophyes mangiferae* Hassan M S) (Bull. Soc. Fouad 1er Entom., XXX, pp. 7-10, 1946).

⁽³⁾ Hall, W.J.: Insect Pests of Citrus in Egypt (Bull. Tech. Sci. Serv., No. 45, pp. 15-16, Ministry of Agriculture, Cairo, 1924).

feeding on fruit stems, so that fruit falls readily; fruit drop in the navel and sukkari oranges and mandarines may be as high as 50%. Mites feeding on the fruit cause scarring and scabbing of the rind, resulting in a lower grade of fruit. Defoliation caused is often very severe and is most noticeable in the last flush of growth and in the tops of trees. Defoliated twigs may die before producing a new set of leaves, in addition to developing gum spots. This type of damage is probably thought to be due to the withertip disease caused by the fungus *Colletotrichum gloeosporioides* ⁽⁴⁾.

Another type of damage has been recently noticed by the writer in citrus, particularly on sweet lime (*Citrus limetta*) and common acid lemon (*Citrus limonia*). Judging by the symptoms, the damage is strikingly similar to that caused by the bud mite *Aceria sheldoni* (Ewing) in California and described by Boyce et al ⁽⁵⁾. The buds develop into an abnormal type of growth, the twigs into a bunched or rosetted type of growth, and the leaves assume irregular shapes.

Mites in general are not susceptible to hydrocyanic acid fumigation. This may be due to the difference in tracheal system between mites and insects. Actually, fumigation is known often to cause an increase in the number of mites ⁽⁶⁾.

Oil spraying is effective in checking mites; but one single application, no matter how thoroughly it is applied, is inadequate for keeping them under control for one single year. An extra treatment that does not involve the use of oil is imperative, because of unfavourable reaction to more than one annual application of oil.

Due consideration, however, must be given to the fact that mites develop resistance to some of the newer insecticides, like the organic phosphorous compounds.

Discussion

The writer who is in charge of pest control operations covering the largest citrus groves in this country from extreme north to south, is impressed by the enormous damage caused by mites to citrus, hardly an orchard being free from mite infestation. It is, therefore, a matter of extreme urgency that the existing pest control programmes shall be revised in the light of the mite problem.

In view of the rapidly increasing citrus export industry, emphasis must be laid on the fact that among the necessary requisites for export is freedom from insects and rind blemishes as is determined by the efficiency of insect control.

⁽⁴⁾ Brown T.W.: The Propagation of Citrus trees in Egypt (Bull. Tech. Sci. Serv., No. 44, Ministry of Agriculture, Cairo, 1936).

⁽⁵⁾ Boyce, A. M., et al: The Citrus bud mite *Eriophyes sheldoni* (Ewing) (*Journ. Econ. Ent.*, XXXIV, p. 745, 1941).

⁽⁶⁾ Quale, H. J.: Insects of citrus and other subtropical fruits (Comstock publishing Company, Inc., Ithaca, New-York, p. 33, 1938).

La véritable identité du scarabée sacré de l'Égypte pharaonique

[Coleoptera : Scarabaeidae-Coprinae]

(avec 1 Figure)

par A. ALFIERI

Le scarabée sacré des anciens égyptiens était vénéré comme le symbole de l'immortalité; c'était l'un des attributs du dieu Phath. On en a retrouvé beaucoup dans les hypogées, faits de matières, de formes, de grandeurs et de coloris les plus divers.

Dans une de ses publications, l'éminent égyptologue Flanders Petrie signale qu'il a cru reconnaître, parmi les amulettes scarabéiformes trouvées dans les nécropoles de l'époque pharaonique, des formes pouvant être assimilées aux genres *Artharsius* (lire *Catharsius*), *Copris*, *Gymnopleurus* et *Hypelogenia* (lire *Hypselogenia*). Evidemment, ce n'est là qu'une hypothèse; car il est très difficile, sinon impossible, d'attribuer, par simple comparaison avec des éléments de la classification zoologique linnéenne, un nom générique précis aux stylisations innombrables apportées dans la fabrication de ces amulettes.

D'autre part, abstraction faite du genre *Hypselogenia* (cétonide inconnu en Égypte), la couleur des représentants de ces genres et d'autres genres (*Helicocopris* et *Bubas*) non mentionnés par Flanders Petrie, est uniformément noire, alors que la plupart des amulettes sont bleuâtres, verdâtres, brunâtres et grisâtres.

Pourquoi devrait-on prendre en considération la forme seulement et ignorer la couleur, telle celle de certaines espèces du genre *Chironitis*, qui sont brunâtres, et celle du genre *Onitis*, qui est verdâtre ? Pourquoi ne pas envisager l'aspect biologique du problème, qui seul permet de diagnostiquer avec certitude le prototype du scarabée sacré !

En effet, toutes les espèces des genres précédemment mentionnés ont des mœurs ténébreuses, travaillent invisibles sous la crôte des déjections fécales, leur présence ne se manifestant qu'à l'approche de la nuit. Autrement

distinctes sont les mœurs des genres *Mnematidium* et *Scarabaeus*. Leurs représentants travaillent constamment à découvert, en pleine lumière, au soleil, édifiant et roulant leur boule en surface et la complétant dans leur terrier. Faites au grand jour, les deux premières phases de cette opération se prêtent à l'observation, ce qui a permis aux anciens égyptiens d'y interpréter le sens hiératique du continuel renouvellement de la vie.



Scarabaeus sacer L.

Le genre *Mnematidium* comprend une seule espèce (*multidentatum* Klug). Au genre *Scarabaeus* appartiennent cinq espèces égyptiennes, à savoir : *cristatus* Fab. (= *cornifrons* Cast.), *gangeticus isidis* Cast.,¹ *puncticollis* Latr., *sacer* L., et *semipunctatus* F. Tous les représentants de ces deux genres sont d'un beau noir légèrement brillant. Ils se ressemblent beaucoup et seul l'œil exercé de l'entomologiste y décèle les caractères morphologiques qui les distinguent entre eux. Le plus commun et le plus répandu à la lisière du désert et dans les campagnes du delta et de la vallée du Nil est sans contredit le *Scarabaeus sacer* L. Il est donc très raisonnable de conclure que c'est seulement lui qui a servi de modèle aux artisans de l'ancienne Egypte dans la fabrication de leurs amulettes scarabéiformes.

Eulecanium taxi nov. spec.

[Homoptera : Coccoidea - Coccidae]

2 (with 6 Text - Figures) 45 54

by A. HABIB, M. Sc., Ph. D., F. R. E. S.,
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During studies on the bionomics of the *Eulecanium corni* (Bouché) - group with special reference to the influence of the host plants, the author found that the differences in size, shape and colour of the adult insects from various host plants are due to the influence of these host plants, and that there are no structural or biological differences between these "host forms". When the immature insects (1st., or even 2nd. instars) were transferred from one species of host plant to another, they showed at maturity the appearance of the form characteristic of the new host plant. The specimens from Yew (*Taxus baccata* L.), however, hitherto referred to as *E. corni* var. *crudum* (Green), were found to be different and separable from *E. corni* (Bouché) on the basis of morphological, biological and behaviour differences.

The word "*crudum*" was originally used by Green as a sub-specific name for the specimens from *Aralia* spec. (England) described as *Lecanium persicae* subsp. n. *crudum* (Green, 1917), and these specimens were designated by him as "type" (on a slide in the British Museum, Natural History). Later, on correcting the erroneously used specific name *persicae* Fab. to *corni* Bouché, Green (1930) referred to these specimens as *L. corni* var. *crudum* Green; in the same paper (page 14), Green recorded the following: "Mr. Fox-Wilson has sent me some branchlets of Yew (*Taxus*) heavily infested by a *Lecanium* that I can only refer to *L. corni* var. *crudum*". Since that time the specimens on *Taxus baccata* have been generally known and identified as *L. corni* var. *crudum* Green (Green, 1934), later as *Eulecanium*.

Gimingham (1934) described the male from *Taxus baccata* under the name of *L. corni* (Bouché).

Examination of Green's "type" and the other slides in the British Museum containing the specimens from *Aralia* sp., showed that structurally they do not differ from the other forms of *E. corni* (Bouché) and apparently

represent only a host form of this species on *Aralia* sp. for which the name *crudum* has to be retained.

The specimens on *Taxus baccata*, both in the British Museum collection and the living specimens available to the author for studies, belong to a species different from *E. corni* (Bouché), not referable to any species of *Eulecanium* Ckll. known to the author, and which is described hereunder.

***Eulecanium taxi* nov. spec.**

Synonyms: *Lecanium corni* var. *crudum* Green, 1930, *Ent. Mo. Mag.*, LXVI, p. 14, female specimens on *Taxus* Spec. - *Lecanium corni* (Bouché), Gimingham, 1934, *Ent. Mo. Mag.*, LXX, pp. 41-42, male. — *Lecanium corni* var. *crudum* Green, 1934, *Ent. Mo. Mag.*, LXX, p. 109, female and male on *Taxus* sp. — *Eulecanium corni* var. *crudum* (Green), Kloet and Hincks, 1945.

A species referable to the genus *Eulecanium* Ckll. (1896), the mature adult female being naked, convex, with the dorsal derm sclerotized; posterior end deeply cleft; anal opening with an invaginated setiferous anal ring, and covered dorsally by a pair of hinged triangular anal plates; margin of the body with simple setae; antennae and legs well developed, normal.

The mature female (Fig. 1) is oval, broadest in the middle, tapering towards both ends, convex, 3.10 mm. long (range 2.40-3.80 mm.), 1.80 mm. wide (1.30-2.30), 1.50 mm. high (1.00-1.90). Anal cleft long and narrow, posterior tips of the margins of the anal cleft deflected outwards. Central carina incomplete, only its posterior part well defined. Dorsal derm smooth and shiny, moderately sclerotised. At the time of oviposition the colour of the



Fig. 1 : Diagram showing the form of the adult and the striations of the dorsum at the time of oviposition.

insect is Capucine orange b. 13. OY. O. (Ridgway : Color standards and Nomenclature), with two dark transverse bands, the cephalic band short and narrow, and the thoracic one much wider and longer. The colour of the dead female after oviposition changes to Sanford's brown, K. II. orange, the transverse bands disappear and the body becomes more or less wrinkled.

On mounted specimens (Figs. 2 and 3) the dorsal derm shows

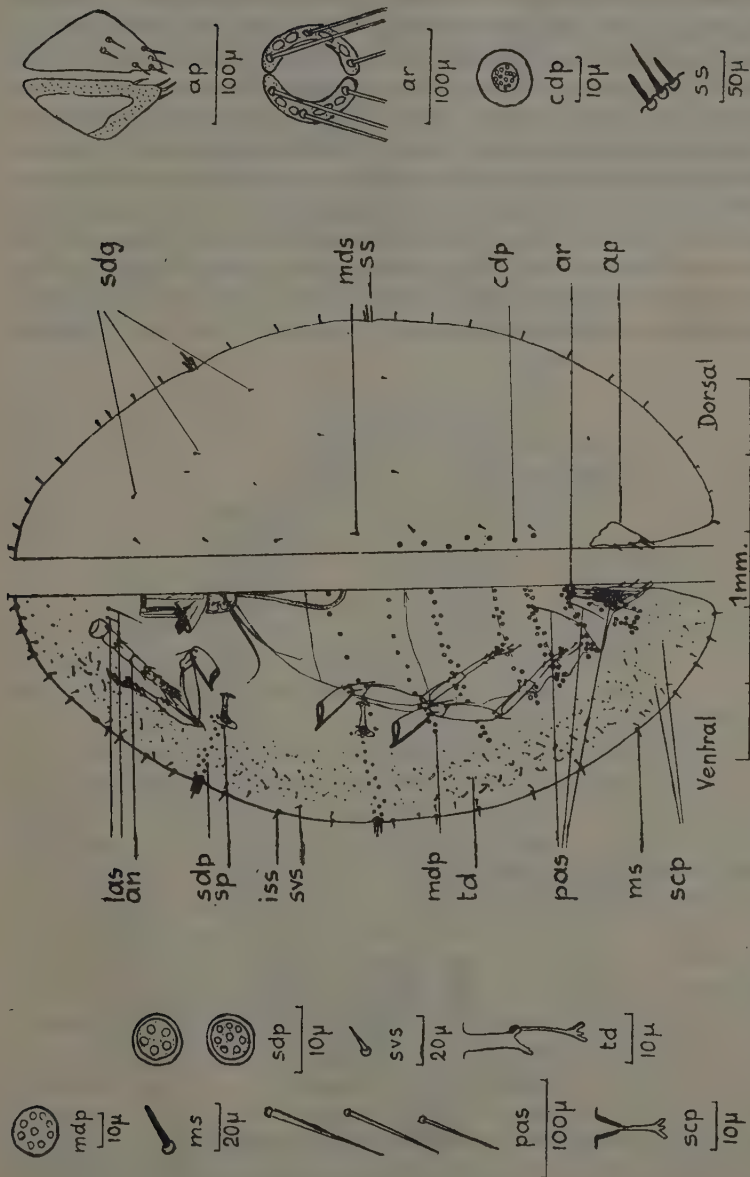


Fig. 2: Young adult female (an, antennae; ap, anal plate; ar, anal ring; cdp, circular dorsal pores; ias, interantennal setae; iss, inter-stigmatic setae; mdp, multilocular derm pores; mds, mid-dorsal setae; ms, marginal setae; pas, pre-anal abdominal setae; scp, small circular pores; sdp, stigmatic derm pores; sds, submarginal dorsal setae; sp, spiracle; ss, stigmatic setae; svs, submarginal ventral setae; td, tubular ducts).

numerous pale areas of various sizes arranged in radiating rows. Antennae 7-segmented, slender, about $300\ \mu$ long, the lengths of the individual segments varying considerably, especially that of the third and fourth segments; the average lengths of the segments in 30 specimens measured were 40, 47, 57, 50, 24, 24, $48\ \mu$, respectively. Eyes marginal, small convex sclerotizations. Legs subequal, about $540\ \mu$ long, slender; tibio-tarsal joint without distinct articulatory process; tarsus distally with two knobbed tenent hairs; claw with small plantar tooth and two digitules both equally long, exceeding by about half the length of the claw; one of these digitules is stout, thick and dilated distally, the other very thin and knobbed. Spiracles with narrow bar, and the spiracular opening about $33\ \mu$ in diameter. The spiracular furrows with 19-25 stigmatic pores arranged in irregular row; these pores mainly quinquelocular, occasionally 6-, 7-, or 8-locular,

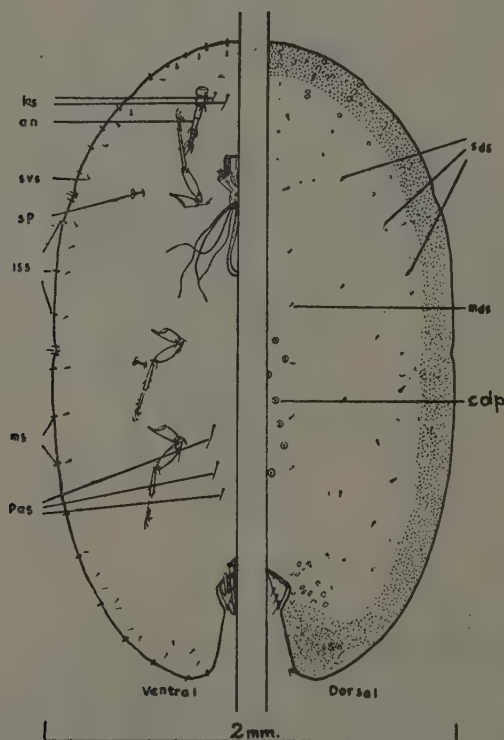


Fig. 3 : Old adult female (same abbreviations as in Figure 2). — Derm pores are always obscure.

especially those near the marginal stigmatic depressions and around the spiracular opening. Three stigmatic setae, two shorter with rounded tips, about $32\ \mu$ long, and between them one longer, about $50\ \mu$ long, pointed. Marginal setae, few, stout, about $18\ \mu$ long, rounded at the apex, more or less evenly distributed along the margin of the body; the number of these setae between the stigmatic depressions on either side (accepted here as a standard number for comparative purposes in order to save time in counting and termed inter-stigmatic setae) varies from 2 to 4 setae (average 2.9). More numerous, smaller (about $12\ \mu$ long) and slender setae arranged in a partly double submarginally ventral row. On the dorsum similar setae are arranged in four longitudinal rows on each side of the median line, the two nearest the median line being regular and of about 7 setae, the other three rows are rather irregular, composed of 4, 4 and 3 setae, respectively. Ventrally, there are 2 or 3 pairs of interantennal setae arranged in a transverse line between the bases of the antennae, the setae of the median pair being the longest; three pairs of abdominal setae arranged in two longitudinal rows anterior to the anal cleft. Anal opening invaginated, the inner wall of the invagination longitudinally striated; with 2 pairs of fringe setae, but no hypopygial setae. Anal ring cellular, rather distinctly divided into two halves, each half with three large anal ring setae. Anal plates together almost quadrate when apposed, each plate about $140\ \mu$ long, and $70\ \mu$ wide at the level of the outer angle; the outer angle rounded; the outer margin slightly longer ($55\ \mu$) than the base ($50\ \mu$); each plate with 4 small apical setae and 2 longer subapical setae; discal setae absent. The ventral multilocular derm pores, 8-10 locular, arranged in seven transverse bands, the most posterior band banding around the anal cleft and composed of numerous pores: anteriorly the number of pores in the bands gradually decreases, the most anterior band being reduced to a single irregular row. The ventral tubular ducts, with long basal tube, asymmetrical cup and tapering inner filament, occupy a narrow submarginal ventral zone around the margin (about $1/6$ of the distance from the margin to the mid-line measured across the middle of the body). Small circular pores with circular external opening about $3\ \mu$ in diameter leading into a conical sclerotized depression about $5\ \mu$ deep with a short membranous internal duct, are scattered among the tubular ducts being especially numerous in the cephalic area and around the anal cleft. Simple circular dorsal pores, anterior to the anal opening, arranged in a median group composed of 12-15 pores (average 13 pores), the distance between the base of the anal plates and the nearest pore being about 3 times the length of the anal plates in fully grown individuals; each of these pores surrounded by an oval, pale area of the derm.

Immediately after the 2nd moult the young adult female is soft, small, 1.85 mm. long (range 0.55 - 2.40 mm.), 1.22 mm. wide (0.96-1.55), flat or slightly convex. Colour Pinkish cinnamon B. 15 Y.O.

Second instar nymph (Fig. 4) of regular oval shape, very flat, small at first, 0.85 mm. long (range 0.75-1.01), 0.47 mm. wide (0.37-0.59); later when fully grown, 1.46 mm. long (1.09-1.76) and 0.85 mm. wide (0.66-0.99). Colour Strawberry pink d. 5.00. R. Stigmatic, marginal,

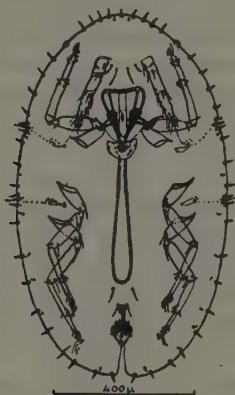


Fig. 4 : Second instar nymph.

submarginal ventral, interantennal and ventral setae, stigmatic derm pores, anal cleft, anal plates and anal ring similar to those of the adult female. Legs stouter. Antennae 6-segmented, stout, the 3rd segment longest and often partially subdivided. There are, however, no multilocular ventral pores on the abdomen, no tubular ducts, no small circular pores and no simple circular or any other type of dorsal pores.

First instar nymph (crawler) (Fig. 5.), of the usual coccid (Lecaniid) type, very flat, oval, rounded anteriorly, tapering posteriorly, with distinct anal cleft and the anal plates situated at the caudal end of the cleft; each anal plate with one long anal and three much smaller (apical) setae at the apex, and one subapical seta. Anal opening with invaginated anal ring carrying 6 anal ring setae; ventral margin of the invagination with one pair of fringe setae. Eyes, a few stigmatic quinquelocular pores, and one pair of interantennal, three pairs of abdominal, a few marginal and three stigmatic setae, are present; antennae 6-segmented, stout; legs, short and stout, with long knobbed tarsal tenent hairs and two knobbed slender digitules on the claw.

Egg, ovoid, about $325\ \mu$ long, $175\ \mu$ wide, with very faint hexagonal pattern on the surface; white at first, later changing to yellow.

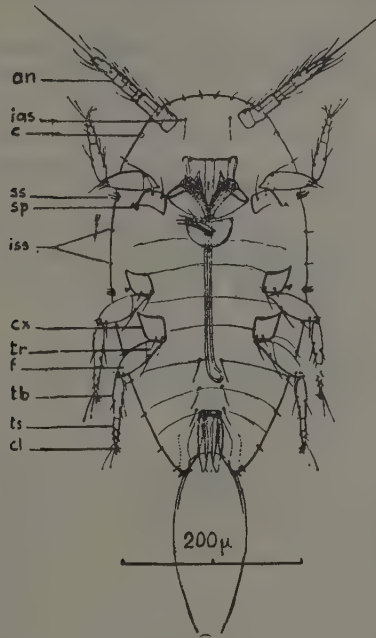


Fig. 5 : First instar nymph.

In the first and second instars the sexes cannot be distinguished, except that at the end of the 2nd instar the male is narrower.

Male puparium (Fig. 6) produced at the end of the second instar is white, elongated oval, about 1.9 mm. long, 0.75 mm. wide; divided into central carina composed of the two plates, and the marginal area com-

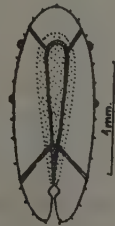


Fig. 6 : Puparium of the male.

posed of one cephalic and two pairs of marginal plates; the anterior plate of the central carina rounded anteriorly, tapering posteriorly, and the posterior plate narrow with pointed posterior end. Under the puparium the male passes through two instars, *pre-pupa* and *pupa*, separated by another moult; the pre-pupa showing rudimental wings, legs and antennal sheaths, the pupa with these sheaths well developed. The pupa moults into the :

Adult male which is of the ordinary coccid type, stout and robust, with broad mesothorax, fore wings well developed, normal; halteres absent. The end of the abdomen truncated with pointed, about $400\ \mu$ long external genital organ; at the base of this organ there is a pair of pits, at the bottom of each pit there is a group of multilocular pores and three long setae projecting posteriorly. Length, including the genital organ, 2.2 mm., wing span 3.2 mm., colour of the body Cinnamon 15 Y.O., blackish head and yellowish antennae and legs.

The male puparium and the male have been already noted (Gimingham, 1934) and described in some details (Green, 1934).

Host plant : *Taxus baccata* L., on the underside of the leaves and twigs.

Distribution : Previously recorded from various localities in the Home Counties (Southern England), where it was reported to cause serious injuries to Yew trees (*Taxus spec.*) (Green, 1934, p. 109). Collected and studied by the author at Silwood Park, Sunninghill, Berks, on *Taxus baccata* L., during 1951-1953.

Apart from being host specific, *E. taxi* can be easily separated from the other species of the genus and especially from *E. corni* (Bouché), with which it was confused, by the following characters of the particular instars :

Adult female smaller size, different colour of the body and reduced striations at the time of oviposition, few stout marginal setae, the group of simple circular dorsal pores composed of few (13) pores with the distance between the base of the anal plate and the nearest pore comparatively large; these and some other characters were statistically analyzed and in all cases confirmed the significance of the differences between *E. taxi* and *E. corni*. The second instar nymph has fewer marginal setae and no submarginal dorsal glands (four pairs of these glands, producing long iridescent filaments, present in *E. corni* at this stage). First instar nymph without the series of ventral pores (ten pairs of such pores present in *E. corni*).

Experiments in reciprocal transfer, and in reciprocal mating of the two species always failed, and testing the fecundity "number of the eggs against the volume of the female" showed different slopes of the regression lines in the two species. The nymphs of *E. taxi* lose their power of locomotion a long time before moulting into adults, while those of *E. corni* retain their power of locomotion till just before the second moult,

The description and figures of the adult female are based on the holotype and 29 paratypes specimens collected at Silwood Park, Sunninghill, Berks, England, 1952; those of the other stages on 30 specimens of each stage collected in the same locality, during 1951-1953, selected at random. Holotype in author's collection, paratype specimens and the material of the other stages, partly in the British Museum, amongst lot 1953-462, and partly in the author's collection.

Brief account of the biology of *Eulecanium taxi*

The species has one generation in the year. The oviposition begins about the middle of May. The number of eggs deposited by a single female varies from 152 to 543 (average 343) and is positively correlated with the size (volume) of the female. The eggs hatch in June. At the time of hatching the nymphs can be seen crawling out from below the anal cleft, usually with the egg-shell still attached to the end of the abdomen. The crawlers are comparatively active, migrating towards the tips of twigs where they can be observed feeding on both surfaces of the leaves. Within a week or two the crawlers finally accumulate on the underside of leaves, leaf-stalks and terminal twigs. The first moult occurs about the middle of August; the 2nd instar nymphs show little activity, late in autumn lose completely their limited power of locomotion and remain immobile permanently fixed for the rest of their lives. During the winter, until April, the nymphs remain without apparent changes in size and shape, and cannot be induced to move by exposure to increased light, temperature, or by drying the leaves. In April, the second moult takes place. In the second half of this month the male puparia are formed and the males emerge in the first half of May. The females complete the second moult late in April, grow rapidly and within a few days reach full size; in the middle of May the oviposition begins.

The males constitute small proportion, about 2% of the total population.

Mortality: No reliable figures were obtained for the mortality of eggs and for the first instar nymphs. Out of the total number of the second instar nymphs counted in August, about 38% reached the adult stage and deposited their eggs.

SUMMARY

The species of *Eulecanium* on *Taxus baccata* L., hitherto referred to as *E. corni* var. *crudum* (Green), is recognized as a distinct species: *Eulecanium taxi* nov. All stages are described together with a short account of the life-cycle.

ACKNOWLEDGMENTS

The work has been carried out at the Imperial College Field Station in the Department of Zoology and applied Entomology. The Author is grateful to Dr. K. L. Boratynski for suggesting the problem, and to him and Dr. W. F. Jepson for their interest in the work. The permission of the Trustees of the British Museum (N. H.) to examine the specimens in the Collection is gratefully acknowledged.

REFERENCES

- Cockerell, A.D.T. (1896) : Check-list of the Coccidae (*Bull. Illinois Sta. Laboratory Nat. Hist.*, IV, pp. 318-339).
- Cockerell, A.D.T. : (1899) Tables for the determination of the genera of Coccidae (*Canad. Ent.*, XXXI, pp. 273-279).
- Cockerell, A.D.T. (1901) : Table to separate the genera and subgenera of Coccidae related to *Lecanium* (*Canad. Ent.*, XXX, pp. 57-58).
- Gimingham, C. T. (1934) : The male *Lecanium corni* Bouché (*Ent. Mo. Mag.*, LXX, pp. 41-42).
- Green, E. E. (1917) : Observations on British Coccidae, No. XII (*Ent. Mo. Mag.*, LIII, pp. 260-269, 4 Figs.).
- Green, E. E. (1930) : Observations on British Coccidae, No. XIII (*Ent. Mo. Mag.*, LXVI, pp. 9-17, 4 Figs.).
- Green, E. E. (1934) : Observations on British Coccidae, No. XIV (*Ent. Mo. Mag.*, LXX, pp. 108-114, 3 Figs.).
- King, G. B. (1901) : The Coccidae of British North America (*Canad. Ent.*, XXXIII, pp. 314-315).
- Kloet, G. S., and Hincks, W. D. (1945) : A check-list of British insects (Stock port).
- Ridgway (1945) : The Color Standards and Nomenclature.
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Nocturnal activity of insects as indicated by light-traps

(with 2 Text-Figures and 3 Tables)

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INTRODUCTION

The fact that many species of insects are attracted and whirl at night around artificial light or its positive phototropism, has long been a common knowledge, and has been investigated by many workers.

The first information on experiments carried in Egypt with light-traps for the control of the various species of cotton worms is to be found in Zervudachi (1910), followed by Willcocks (1916, pp. 314-135, and 1922, pp. 10-23).

Later on, Willcocks and Bahgat (1937, pp. 702-755) gave a full historical account on the subject, stating that the use of light-traps in the Country occurred as early as from 1900, and up to 1923. Apparently, no conclusive results were reached.

An attempt was made by Balls (1920) to obtain informations on the effect of meteorological conditions on the activity of moths and the number of night catches, but he could not reach a definite conclusion.

Williams (1923), in Egypt, devised a new light-trap lighted by a globe closed completely beneath. If electricity is used the bulb is lowered into it from above, but if acetylene is the origin of light the burner and chimney should be used in order to set up a proper circulation.

Husain, Khan, and Ram (1934), in their experiments on *Platyedra gossypiella* in Punjab, divided the nights in three periods of four hours each. Trapping was carried out in September and October during the years 1929-1931. In September 1929 and 1931 the results showed maximum flight in the last period of the night, in mid-night at the middle of the test, and in the early period of the night towards the end. In September 1930, the maxima occurred in the middle period.

A short account on his experiments with light-traps is given by Bishara (1934).

Williams (1935) used a light-trap under which eight killing bottles were arranged by a clock mechanism through which the bottles change at any desired time during the night. The period of exposure for each bottle ranged from 50 minutes at mid-summer to just under two hours at mid-winter. The insect ditribution showed a maximum at the beginning of the night in both first and second periods, and a steady fall to about half the numbers in the last. The catches from 1933 to 1937 were 109,344, 103,326, 399,006, and 242,822, respectively. The arithmetic mean catches per night were 309, 287, 1102, 728, respectively; but the geometric means which give a better indication of comparative abundance, were 37, 53, 54 and 64.

A light-trap at a height of 35 feet (10.6 metres) caught several species of Noctuidae which were absent or rare in the lower trap. Certain species of Lepidoptera were shown to vary considerably in the sex-ratio from year to year. The proportion of females caught increased in many species during the course of the brood.

Williams (1940) analysed the results in so far as they threw light on the influence of weather conditions on the catches. The catch was dependent chiefly, apart from the environmental conditions, on factors of activity and population. The maximum catch was correlated with the minimum temperature of the previous day, the effect of maximum temperature alone was smaller than that of minimum temperature.

OBJECT OF THE EXPERIMENTS

Similar studies and observations were made in the fields of the Faculty of Agriculture at Shebin El-Kom, to obtain a measure of the population density of some lepidoptera, and particularly as to date of appearance, relative length of the brood, and the relation of their abundance to the environmental conditions.

DESCRIPTION OF THE TRAPS

The traps used (Fig. 1) are based on that originally made in Egypt by Williams (1924).

The dimensions of the trap are : width 24 inches, height to top of the table 40 inches, to light 45 inches. Beneath the light, the central glass-chamber is closed by a zinc funnel which lead to a cyanide killing bottle. The source of the light is a 200 Watt, the candle power is approximately 400.

Two traps were started in regular use on first January 1952, and two more traps were used on first of January 1953. The traps were about 100 metres apart in the fields. They were operated each daily, from dusk to

dawn. Each morning the catches were removed from the traps, and the contents of each bottle sorted into insect orders. Some of the macrolepidoptera and microlepidoptera were sorted into species and sexes.



Fig. 1 : Light-trap at Shebin El-Kom

SURVEY OF CAPTURES

The total numbers of insects captured in the first year were 387.737 and 354.302, in the second year 370.262, 361.692, 343.711, and 413.657.

The arithmetic mean catch per night were 1.060 and 969 (1952), and 1.006, 985, 936, and 1.126 (1953).

The geometric mean gives different results: 337.330 (1952), 275, 252, 257 and 229 (1953).

Figure 2 shows the change in the two year of arithmetic and geometric mean catch per night in each month of the year.

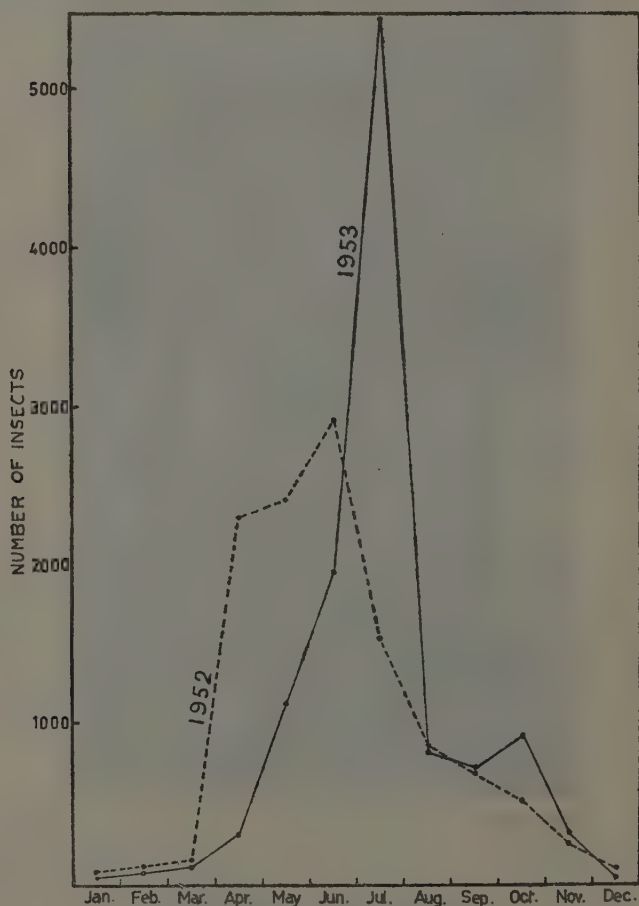


Fig. 2 : Arithmetic mean catch per night.

The number of insects on both number and logarithmic basis is at its lowest during January and December, and at its highest during June and July.

There is a correlation between the mean geometric catch per night and the mean minimum temperature at Shebin El-Kom for nine years (1945-1953) (Table I). This shows that temperature is a factor contributing most largely to annual fluctuation in insect population. These results confirm those of Williams (1939) in regard to the relation between minimum temperature and the mean catch per night.

TABLE I

Relation between the geometric mean catch per night in two years, and mean minimum temperature in each month of the year.

MONTH	TWO YEARS GEOMETRIC MEAN CATCH PER NIGHT	NINE YEARS (1945-1953) MEAN MINIMUM TEMPERATURE	ORDER OF MINIMUM TEMPERATURE
July	3518	18.7	1
June	1778	16.4	2
May	896	13.2	5
August	802	16.3	3
September	721	16.0	4
October	705	13.1	6
April	561	7.8	7
November	181	7.7	8
March	71	5.9	9
February	55	4.1	11
December	30	5.7	10
January	23	3.4	12

DISTRIBUTION OF THE CATCH IN DIFFERENT ORDERS

The distribution of the catch in two traps (1952) and four traps (1953), subdivided according to the orders of insects, is shown in Table II. Actual counts show that Diptera constitutes 78.55 % of the catch in the two years. It occurred in each month of the year and reached its maximum of activity in July.

Homoptera is the next most abundant group constituting an average of 14.98 %, and reaching its maximum in June. It appeared in all months of the year, the majority being Jassids and Aphids.

Lepidoptera's average is 2.79 %, and it appeared all over the year.

Coleoptera's average is 2.22%.

The remainder of insects, altogether, makes up only 1.5 % of the catch. Collembola constitutes 0.98 % of the catch in the two years and occurred in numbers with a maximum in March, and were nearly absent from May to August.

Trichoptera occurred in a large number in August and were nearly absent from December till March.

TABLE II

Total captures of each order, and percentage per month throughout the two years.

ORDER	TRAP I			
	YEAR 1952		YEAR 1953	
	CAPTURES	PERCENTAGE	CAPTURES	PERCENTAGE
Diptera	286869	74.0100	277269	74.8900
Homoptera	70372	18.1300	76616	20.6900
Lepidoptera	13788	3.5600	7095	1.9200
Coleoptera	11688	3.0100	5509	1.4900
Collembola	1986	0.5200	2688	0.7050
Hymenoptera	1846	0.4700	144	0.0380
Hemiptera	643	0.1600	17	0.0005
Trichoptera	301	0.0700	426	0.1160
Orthoptera	145	0.0470	277	0.0740
Neuroptera	75	0.0230	168	0.0450
Dermaptera	19	0.0050	9	0.0020
Ephemeroptera	4	0.0017	35	0.0010
Isoptera	1	0.0003	12	0.0003

ORDER	TRAP II			
	YEAR 1952		YEAR 1953	
	CAPTURES	PERCENTAGE	CAPTURES	PERCENTAGE
Diptera	258234	72.8900	293798	81.2300
Homoptera	66638	18.8200	51710	14.3000
Lepidoptera	12307	3.4700	8957	2.5800
Coleoptera	11048	3.1300	3455	0.9600
Collembola	3335	0.9500	2744	0.7600
Hymenoptera	1647	0.4640	115	0.0050
Hemiptera	467	0.1320	61	0.0030
Trichoptera	7	0.0050	530	0.1800
Orthoptera	8	0.0000	149	0.0060
Neuroptera	89	0.0040	133	0.0046
Dermaptera	13	0.0003	6	0.0003
Ephemeroptera	8	0.0020	34	0.0010
Isoptera	1	0.0001	1	0.0001

ORDER	TRAP III (YEAR 1953)		TRAP IV (YEAR 1953)	
	CAPTURES	PERCENTAGE	CAPTURES	PERCENTAGE
Diptera	286669	83.4000	352925	85.3100
Homoptera	33009	9.6000	38655	9.3400
Lepidoptera	7590	2.2400	9437	2.2800
Coleoptera	5553	1.6200	10014	2.4400
Collembola	9280	2.7200	980	0.2400
Hymenoptera	197	0.0600	57	0.0060
Hemiptera	30	0.0090	128	0.0300
Trichoptera	599	0.1600	761	0.1800
Orthoptera	525	0.1500	509	0.1240
Neuroptera	134	0.0400	151	0.0420
Dermaptera	8	0.0002	12	0.0034
Ephemeroptera	14	0.0004	19	0.0045
Isoptera	13	0.0004	5	0.0001

The majority of Neuroptera were chrysopids, with small number of myrmelionids. The maximum of their catch was in July.

Orthoptera reached their maximum in July and September. Most of them were gryllids and mantids.

Hymenoptera, Dermaptera, Ephemeroptera and Isoptera were less abundant in the traps.

Lepidoptera

The Lepidoptera were sorted into families and those of economic importance were identified and sexed. They constituted the 2.79% of the catch in the two years, and they reached their maximum abundance in May.

Table III shows the identified families captured in four traps during 1953.

Notes on the date of appearance and the sequence of broods were taken on the important species of the Noctuidae. The Sphingidae, Lasiocampidae and Cossidae were identified and sexed. Pyralidae were the most abundant, reaching their maximum activity in May, June and September, and were followed in importance by the Tineidae, Plutellidae and Gelechiidae.

Sphingidae

Celerio lineata livornica Esp. (the Striped Hawk Moth). — Its larva feeds on vines and other cultivated plants. The species is active in March and April. The captured females outnumber the males, i.e. 4 females to 2 males. K. Grant (1937) suggests that there seems to be some correlation between the outbreak of the species and the sunspot cycle, but the figures are barely significant. The outbreaks tend to occur away from sunspot minima.

Hippotion celerio L. is not common in the traps and only one individual was captured in April, 1953.

Theratra electo cretica Boisd. was captured during 1953, in April and May. Four moths were caught, three females and one male.

Deilephila nerii L. — Two samples were captured during September and October, 1953.

Herse convolvuli L. occurred in May, June and October. Four specimens were captured, two females and two males.

Lasiocampidae

Anadiasa undata Klug. — The annual fluctuation of this species during the course of the study shows seasonal flight period. The first date of its appearance in the traps was April, 25 th. The species was attracted in considerable number from April to September, with great majority in June. The captured moths during 1953 were 337 males and 112 females, the percentage

of females being 24.9 %. The species is double brooded, with a short interval in between. The first brood (April-June) is much more abundant than the second one (July-September).

Nadiasa acaciae Klug. — This beautiful moth appeared in the traps from May to August. The first appearance was in May, 3rd. The numbers caught indicate that females were proportionally less than males, the ratio being 1:3.

Lasiocampa serrula aegyptiaca Ob. — The seasonal flight of this species occurs on June-August, and September. The first catch occurred on the first of June. A total of 9 males to 4 females (30.7 %) were captured.

Zeuzera pyrina L. (the Leopard Moth). — Apple, pear and pomegranate are the most common host plants of this species, which also infests ornamental and forest trees. Eight samples were captured in the traps, 5 females and 3 males. The moths are on the wing in May and June.

Cossus L-nigrum B.-Baker. — A most abundant species caught in the trap during June-August. The captured females outnumbered the males, 35 males to 41 females (53.9 %).

Paropta paradoxa H.S. — The first samples was caught on June 5th, followed by five more individuals captured during June and July, 1953.

Noctuidae

Special attention was given to members of this family for their economic importance.

Prodenia litura F. — The damage done by this main pest of cotton and clover in Egypt is well known.

According to Willcocks and Bahgat (1937), light-traps were tried by the "Sucreries Society of Egypt" in an attempt to prevent the cotton worm ravaging sugarcane under experiment. *Prodenia litura* F. and *Laphygma exigua* Hubn., both in the moth stage, could be trapped readily, but the crop was not saved. In experiments of Andres-Maire, light-traps were used together with an attractant registered as "Prodenine". Continuous catches with Andres-Maire moth-traps were recorded at Dokki from 1919 to 1923. The females entrapped in 1920 and 1921 were more numerous than the males.

On the other hand, the trapping of *Prodenia litura* F. at Shebin El-Kom, in 1952, represented 198 moths, of which 96 females and 102 males, with a percentage of 46.5 to the females. In 1953, the catch was 359 moths in the four traps, of which 171 females and 188 males, with a percentage of 48 to the females. The moths were captured in all months of the year. The first moths appeared in January 4th, 1952, and in January 6th, 1953, respectively. The seasonal broods show no definite break during the year, and also show the

abundance of the pest. From January to the end of March there are few catches, the moths being mostly in the pupal stage. The winter brood is about three to four months. The second brood, is the outcome of the winter brood. It occurs in April and May, with a maximum catch during May, and is followed by the June and July brood which is the biggest and the most troublesome, as it seriously injures the cotton crop. The peak of this brood occurs during June and July. From about the end of August and throughout September and October, there is a fourth generation which attacks corn and early sown clover. The maxima occurs during October. The brood that follows occurs in November and December, and causes damage to the clover crop.

At Shebin El-Kom one may count five broods during the year, but they are not sharply defined.

Laphygma exigua Hb. (the Lesser Cotton Worm, which is called in the Sudan the Cotton Seedling Worm) is a serious pest of different crops and is widespread in the world. In Egypt, it attacks cotton, berseem, maize and various leguminous crops.

The first brood, which is a small one, seems to occur during March and the first week of April. The moths are scarce and begin to appear in small numbers.

The second brood occurs during the latter half of April and May. The pest reaches its peak and activity during May. This brood attacks cotton and clover.

The third brood is the highly abundant one during June and July. It is the most injurious as regards damage to cotton. The fourth brood occurs during August and the first week of September, and moths are captured in small numbers in the traps.

The fifth brood represents the second period of high activity of the pest. It occurs during the latter period of September and October, and attacks corn.

The sixth brood takes place during November and December. The number of trapped moths began to decrease owing to cold weather.

During 1952, 368 moths were captured, of which 189 males and 181 females, the females constituting 49.9 % of the moths. The moths captured during 1953 amounted to 251 (125 males and 126 females), the percentage of the females being 50.02. It is clear from the above data that the proportion of females is nearly equal to the males.

Agrotis ypsilon Rott. (the Greasy Cutworm). — The account of the investigations carried on the greasy cutworm show that there are four broods. The first brood started and occurred after the summer migration in late September and October. In the second brood, moths made their appearance from the end of October till early December. The peak seasonal increase

is the third brood which occurs during March and April. In the fourth brood the moths appears about the end of May and June. Investigations show that moths of *A. ypsilon* are not attracted during the latter week of July and August. Furthermore, the moths disappear during summer time, and such behaviour is explained by different research workers through the fact that the species is a migratory one.

The moths caught in 1952 amounted to 136 (55 males and 81 females), the percentage of the females being 59.5. The captured moths during 1953 numbered to 150 (80 males and 70 females), with a percentage of 46.6 for the females. The proportion of the females in the two years was 52.5%.

Agrotis spinifera Hb. (the Cutworm). — Investigations carried during the two years trapping have shown, in the whole, that *A. spinifera* is found throughout all the months of year. Although the moths are trapped in summer, there was a big catch during the spring and the autumn, and very abundant captures in the traps during April and November.

In 1952 the catch was 58 moths (29 males and 29 females), the proportion of sexes being equal. In 1953, 170 moths were caught (92 males and 78 females), the percentage of the females being 45.9.

Phytometra gamma L. (the Silver-Y Moth) is one of the commonest moths in many countries. The movement of the species was studied by Fisher (1938) in England, where very rarely single specimens were caught as late as November. Although swarming was present at the beginning of October, they disappeared suddenly about the middle of the month and no trace was seen until the following spring.

The occurrence of the unusual abundance of the moths in different nights of March and April 1952 and the records of mass flight in this period, indicate that *Phytometra gamma* L. is a migratory species in Egypt.

The species has two broods during the year, the first brood occurring during March, April and May, with the first moths appearing on January 30th, 1952, and on January 31st, 1953, respectively. The second brood appeared during 31st November.

In 1952, the males were more attracted than the females. The captured moths were 647 (339 males and 308 females), with 47.6% of females. During 1953, the catch was 138 moths (62 males and 76 females), thus 57.9% of females. The percentage of the females in the two years was 49.7.

Syngrapha circumflexa L. — This species is common in Egypt. The available recorded catches suggest that there were two broods. The first brood is during the end of February and April. No specimens were caught during June and July, 1952. The moths appeared scarcely during the summer months in 1953. The first catch dated March 6th, 1952, and February 25th, 1953. The moths reached their peak during April in the two years. The second brood occurred during November and December. Moths were caught

in small numbers in these months. The species is evidently on the wing during spring and autumn. The total catch was 203 moths in 1952. The males amounted to 123 and the females to 80, with a percentage of 39.4. The catch in 1953 represented 201 moths (123 males and 78 females), with a percentage of 38.8 of females. The proportion of sexes in the two years was 3 males : 2 females, and thus males outnumber females.

Chloridae obsoleta F. (the American Bollworm, also known as the Corn Earworm and Tomato Fruitworm), is a cosmopolitan pest of major importance. In Egypt, the insect population is apparently low.

The species is double brooded, the first brood occurring from April till July. Small numbers were captured during February and March. The peak of activity was recorded during April and May. The second brood is less abundant. The emergence of moths took place during October, November and December. Our records indicate that 60 moths were caught during 1952, the sex-ratio being 1:1. During 1953, the catch was 58 moths (31 males and 27 females).

Earias insulana Boisd. (the Spiny Bollworm) is an old world tropical and sub-tropical species. It is an important pest of cotton and other malvaceous plants in different parts of the world.

In Egypt, it is usually found from the last week of July and up to December. The moths were caught once in each of the months of January, February and March. It reached its peak of activity and abundance in the two years (1952 and 1953) during September and October. In 1952, 243 moths (152 males and 91 females) were captured. During 1953, the catch reached 622 individuals, of which 439 were males. The ratio of the males to the females is, therefore, 3:1.

Pyralidae

Chilo simplex Butler (the Rice Borer) has been present in Egypt for many years and is widely distributed in the Country. It is an important pest of corn and breeds in rice as well.

The species has two broods: the first one starts in the first week of June, reaches its peak during the first week of August, and is over by the third week of August; the second brood starts during September and reaches its peak during October and continues to November.

The catch reaches its maximum during October. 102 moths were caught during 1952, of which 59 were males and 43 females. In 1953, the captured moths were 922, of which 575 males and 347 the females. The percentage of the females was 7.4, and the males outnumbered the females in the two years (1952-1953).

Pyrausta nubilalis Hbn. (the European Corn Borer) is one of the most

injurious pest of corn in Egypt. The moths were evidently on flight during April-July and September-December. The first date of appearance was April 10th, 1952, and April 7th, 1953.

Pyrausta nubilalis has two complete and distinct broods. The first brood was light and started from April till June, during 1952. In 1953, it continued till July. The moths were numerous in May, 107 moths being caught in this month during 1952, and 166 during 1953. The second brood started in August and occurred during September-November. The moths were very numerous and reached their peak of activity and abundance during September and October. In 1952, the captured moths were 967 (707 males and 260 females, or 27%). The catch of 1953 numbered with 1224 moths (984 males and 238 females, or 19.5%). The ratio in the two years was 4 males per one female.

SUMMARY

Investigations were carried out to study the nocturnal activities, abundance and population density of different insects as indicated by light-traps in the fields of the Faculty of Agriculture at Shebin El-Kom (Menoufieh), Egypt.

Two light-traps were exposed almost every night from January 1st to December 31th, 1952. Two more ones were used in the following year.

The source of light is a 200 Watt, the candle power is approximately 400. The light in the trap was about 120 cm. from the ground.

The total numbers of insects captured in 1952, in the two traps, were 387.737 and 354.302. In 1953, the four light-traps captured 370.262, 361.692, 343.711, and 413.657 samples. The arithmetic mean catches per night were 1060 and 969 (1952), and 1006, 985, 936 and 1126 during 1953. The geometric mean catches per night were 337 and 330 (1952), and 275, 252, 257, and 229 during 1953. The highest average catch was during July, the lowest in January.

Diptera constituted 78.55% of the catch in the two years. Homoptera 14.9%, Lepidoptera 2.79%, Coleoptera 2.22%, while all other insects constituted 1.5%.

The sequence of broods in a number of species of Lepidoptera is discussed and their sex proportion is listed.

The cotton leaf-worm was captured in all months of the year and there was no definite break in the brood during the year. The peak and maximum of abundance was during June and July. The percentage of the females to males was 47.25%.

The Lesser cotton worm, *Laphygma exigua* Hb., was captured from March to December. The variation of the captures and date of occurrence show that the pest has six generations throughout the year. The sex-ratio is nearly 1:1.

In the Greasy cut-worm, *Agrotis ypsilon* Rott., there are four broods. The peak seasonal increase occurs during the third brood, in March and April. The moths caught are more numerous in April. During the latter week of July and August, the moths disappeared and no catches could occur.

This behaviour confirms the evidence of its migratory habits. The sex ratio in the two years was nearly 1:1 (52.5% females).

Observations on the Cut Worm, *Agrotis spinifera* Hb., show that moths were caught during summer months; moreover, there was a big catch of moths in spring and autumn. The percentage of females to males was 45.9.

The seasonal distribution of the Silver-Y moth, *Phytometra gamma* L., indicates the unusual abundance of adults in different nights of March and April. Records of mass flights during this period indicate that the species is migratory in Egypt. The females are nearly equal to males.

Records of *Syngrapha circumflexa* L. show that the species is double brooded, and that the proportion of sexes was 3 males : 2 females

Data of the catch of the American bollworm, *Chloridea obsoleta* F., shows that the species is also double brooded, and that the sex-ratio is approximately equal.

In the Spiny bollworm, *Earias insulana* Boisd., the insect reached its peak of activity in the two years during September and October. The proportion of sexes was 3 males for 1 female.

Observations on the catch of moths of the Rice borer, *Chilo simplex* Bat., show that the species is double brooded and reached its maximum of activity in October. The captured males outnumber the females.

The study of the catch of the European corn borer, *Pyrausta nubilalis* Hbn., shows that the species is also double brooded. The first brood is light and starts from April to July, and the second from August to November. The moths are abundant during September and October. The sex-ratio was 4 males : 1 female.

The sequence of broods and appearance of number of species of families Sphingidae, Lasiocampidae and Cossidae is discussed. The annual fluctuations of some species shows seasonal flight period.

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REFERENCES

- Andrews, H. L. (1931): Moth trap experience in Dorset (*Entomologist*, LXIV, pp. 86-90, and 104-106).
- Ballou, H. A. (1920): The pink boll worm in Egypt in 1916-1917 (Ministry of Agriculture, Cairo).
- Bishara, Ibrahim (1932): The Greasy cut worm, *Agrotis ypsilon* Rott., in Egypt (Bull. No. 114, Technical and Scientific service, Ministry of Agriculture, Cairo).
- Bishara, Ibrahim (1934): The cotton worm, *Prodenia litura* F., in Egypt (*Bull. Soc. Roy. Ent. Egypte*, XVIII).
- Bogush, P. P. (1936): Some results of a study of insects by means of light traps in central Asia (*Bull. Ent. Res.*, XXVII, pp. 377-380).
- Campbell, R. E., and Duran, V. (1929): Notes on the sugar beet army worm in California (Monthly Bull., Dept. Agr. Calif., XVII, pp. 267-275).
- Caffrey, D. J., and Wothley, L. H. (1927): The European corn borer, its present status and methods of control (U.S. Dept. Agric., *Farmers Bull.* 1548, p. 48).
- Cook, W. C. (1921): Studies on the flight of nocturnal Lepidoptera (Report No. 18, State Ent. Minnesota, 1920, pp. 43-56).
- Cook, W. C. (1930): Field studies of the pale Western Cutworm (Tech. Bull. 225, Montana Agr. Exp. Stat., p. 11).
- Davis, E. G., and Horton, J. R. (1933): The Southwestern corn borer (U.S. Dept. Agr., *Farmers Bull.* 1548, pp. 48).
- Fletcher, T. B. (1925): Migration as a factor in pest outbreaks (*Bull. Ent. Res.*, XVI (2), pp. 177-181).
- Fisher, Katherine (1937): An historical study of the migration of *Celerio lineata lineata* Fab., and *Celerio lineata livornica* Esp., Lepidoptera (*Trans. Royal Entom. Soc. London*, LXXXVI, pp. 345-375).
- Fisher, Katherine (1938): Migration of Silver-Y moth, *Plusia gamma*, in Great Britain (*Jour. Animal Ecol.*, VII, pp. 230-247).
- French, R. A. (1951): Lepidoptera at light in a Hertfordshire wood in July 1949 (*Entomologist*, LXXXIV, pp. 49-55).
- Gillette, C. P. (1900): The beet army worm *Laphygma exigua* (Colorado Agr. Exp. Station, Rept. 12, page 39).
- Gunton, H. C. (1935): Phenological records of British Lepidoptera (*Quart. J. R. Meteorol. Soc.*, LXI, pp. 417-424).
- Hassan, A. (1951): Economic insects in Egypt (in Arabic, 700 pages, Cairo).
- Husain, M. F., Khan, M. H., and Ram, G. (1934): Studies on *Platyedra gossypiella*, the Pink boll worm of cotton in the Punjab (*Ind. J. Agric. Sci.*, IV, pp. 244).

- Kono, Y. (1936): Kerosene lamps as light traps for *Chilo simplex* in Japan (*Nojikairyo-shiryō*, CIX).
- Pinchin, R. D., and Anderson, J. (1936): On the nocturnal activity of the Tipulinae (Diptera) as measured by a light trap (*Proc. R. ent. Soc. Lond.* (A), II, pp. 69-78).
- Robertson, A. G. (1939): The nocturnal activity of crane flies as indicated by captures in a light trap at Rothamsted (*Jour. Animal Ecology*, VIII, pp. 300-322).
- Robinson, H. S., and Robinson, P. J. M. (1950): Some notes on the observed behaviour of Lepidoptera in flight in the vicinity of light sources, together with a description of a light trap designed to take entomological samples (*Entom. Gaz.*, I, pp. 3-20).
- Squire, F. A. (1937): Nocturnal habits of *Platyedra gossypiella* Saunders (*Nature*, CXL, No. 3532, pp. 69-70).
- Vickery, R. A. (1929): Studies on the fall army worm in the Gulf coast district (U.S. Dept. Agric. Tech. Bull. No. 138, pp. 1-63).
- Wheeler, N. H. (1937): Trap-light studies on Leafhoppers belonging to the genus *Empoasca* (Homoptera: Cicadellidae), with the description of two new species (*Proc. ent. Soc. Washington*, XXXIX, pp. 141-156).
- Williams, C. B. (1923): A new type of light trap for insects (Bull. 28, Tech. and Scientific Service, Ministry of Agriculture, Cairo).
- Williams, C. B. (1935): Notes on insects migration in Egypt and the near East (*Trans. Entom. Soc. Lond.*, XXIII).
- Williams, C. B. (1935): The time of activity of certain nocturnal insects, chiefly Lepidoptera, as indicated by a light trap (*Trans. R. ent. Soc. Lond.*, XXIII, pp. 523-555).
- Williams, C. B. (1936): The influence of moon-light on the activity of certain nocturnal insects, particularly of the family noctuidae as indicated by a light trap (*Phil. Tran. Roy. Soc. Lond.*, CCVI, pp. 357-389).
- Williams, C. B. (1937): The use of logarithm in the interpretation of certain Entomological problems (*Ann. Biol.*, XXIV, pp. 404-414).
- Williams, C. B. (1939): An analysis of four years captures of insects in the light trap (*Trans. R. ent. soc. Lond.*, LXXXIV, pp. 79-132).
- Williams, C. B. (1947): The logarithm series and its application to biological problems (*Jour. Ecology*, XXXIV, pp. 253-272).
- Williams, C. B. (1951): Comparing the efficiency of the insect traps (*Bull. entom. Res.*, XLII, pp. 513-517).
- Willcocks, F. C. (1916): The Insect and related pests of Egypt, I, part 1, (Sultanic Agricultural Society, Cairo).
- Willcocks, F. C. (1922): A survey of the more important economic insects and mites of Egypt (Bulletin No. 1, Technical Section, Sultanic Agricultural Society, Cairo).

- Willcocks, F. C., and Bahgat, Said (1937) : The insects and related pests of Egypt, I, part 2 (Royal Agricultural Society, Cairo.).
- Zervudachi, Georges C. (1910) : Note sur le ver du cotonnier et sur le moyen de le détruire (3 fascicules : Janvier, Juillet et Octobre, respectivement).
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العدد الأربعين السنة التاسعة والأربعون

مجلة
الجمعية المصرية لعلم الحشرات

(الجمعية الملكية المصرية لعلم الحشرات (١٩٣٧ - ١٩٢٢)

وجمعية فؤاد الأول لعلم الحشرات (١٩٣٨ - ١٩٥٤))



تأسست في أول أغسطس سنة ١٩٠٧

وضعت تحت رعاية الحكومة المصرية بمرسوم

في ١٥ مايو سنة ١٩٢٣

القاهرة

الاتحاد المصري للطباعة

١٩٥٦

